Université de Montréal

Trois essais en macroéconomie

par

Gabriel Bruneau

Département de sciences économiques
Faculté des arts et des sciences

Thèse présentée à la Faculté des études supérieures et postdoctorales
en vue de l'obtention du grade de Philosophiae Doctor (Ph.D.)
en sciences économiques

Mars 2015

Université de Montréal
Faculté des études supérieures et postdoctorales

Cette thèse intitulée

Trois essais en macroéconomie

par

Gabriel Bruneau

a été évaluée par un jury composé des personnes suivantes :

Président-rapporteur :	Rui Castro
Directeur de recherche :	Francisco Ruge-Murcia
Examinateur externe :	Hashmat U. Khan
Membre du jury :	Immo Schott
Représentant du Doyen :	Manuel Morales

Résumé

Les fluctuations économiques représentent les mouvements de la croissance économique. Celle-ci peut connaître des phases d'accélération (expansion) ou de ralentissement (récession), voire même de dépression si la baisse de production est persistente. Les fluctuations économiques sont liées aux écarts entre croissance effective et croissance potentielle. Elles peuvent s'expliquer par des chocs d'offre et demande, ainsi que par le cycle du crédit. Dans le premier cas, les conditions de la production se trouvent modifiées. C'est le cas lorsque le prix des facteurs de production (salaires, prix des matières premières) ou que des facteurs externes influençant le prix des produits (taux de change) évolue. Ainsi, une hausse du prix des facteurs de production provoque un choc négatif et ralentit la croissance. Ce ralentissement peut être également dû à un choc de demande négatif provoqué par une hausse du prix des produits causée par une appréciation de la devise, engendrant une diminution des exportations. Le deuxième cas concerne les variables financières et les actifs financiers. Ainsi, en période d'expansion, les agents économiques s'endettent et ont des comportements spéculatifs en réaction à des chocs d'offre ou demande anticipés. La valeur des titres et actifs financiers augmente, provoquant une bulle qui finit par éclater et provoquer un effondrement de la valeur des biens. Dès lors, l'activité économique ne peut plus être financée. C'est ce qui génère une récession, parfois profonde, comme lors de la récente crise financière.

Cette thèse inclut trois essais sur les fluctuations macroéconomiques et les cycles économiques, plus précisément sur les thèmes décrit ci-dessus. Le premier chapitre s'intéresse aux anticipations sur la politique monétaire et sur la réaction des agents écononomiques face à ces anticipations. Une emphase particulière est mise sur la consommation de biens

durables et l'endettement relié à ce type de consommation. Le deuxième chapitre aborde la question de l'influence des variations du taux de change sur la demande de travail dans le secteur manufacturier canadien. Finalement, le troisième chapitre s'intéresse aux retombées économiques, parfois négatives, du marché immobilier sur la consommation des ménages et aux répercussions sur le prix des actifs immobiliers et sur l'endettement des ménages d'anticipations infondées sur la demande dans le marché immobilier.

Le premier chapitre, intitulé "Monetary Policy News Shocks and Durable Consumption", fournit une étude sur le lien entre les dépenses en biens durables et les chocs monétaires anticipés. Nous proposons et mettons en oeuvre une nouvelle approche pour identifier les chocs anticipés (nouvelles) de politique monétaire, en les identifiant de manière récursive à partir des résidus d'une règle de Taylor estimée à l'aide de données de sondage multi-horizon. Nous utilisons ensuite les chocs anticipés inférer dans un modèle autorégressif vectoriel structurel (ARVS). L'anticipation d'une politique de resserrement monétaire mène à une augmentation de la production, de la consommation de biens non-durables et durables, ainsi qu'à une augmentation du prix réel des biens durables. Bien que les chocs anticipés expliquent une part significative des variations de la production et de la consommation, leur impact est moindre que celui des chocs non-anticipés sur les fluctuations économiques. Finalement, nous menons une analyse théorique avec un modèle d'équilibre général dynamique stochastique (EGDS) avec biens durables et rigidités nominales. Les résultats indiquent que le modèle avec les prix des biens durables rigides peut reproduire la corrélation positive entre les fonctions de réponse de la consommation de biens non-durables et durables à un choc anticipé de politique monétaire trouvées à l'aide du ARVS.

Le second chapitre s'intitule "Exchange Rate Fluctuations and Labour Market Adjustments in Canadian Manufacturing Industries". Dans ce chapitre, nous évaluons la sensibilité de l'emploi et des heures travaillées dans les industries manufacturières canadiennes aux variations du taux de change. L'analyse est basée sur un modèle dynamique de demande de travail et utilise l'approche en deux étapes pour l'estimation des relations de cointégration en données de panel. Nos données sont prises d'un panel de 20 industries ma-

nufacturières, provenant de la base de données KLEMS de Statistique Canada, et couvrent une longue période qui inclut deux cycles complets d'appréciation-dépréciation de la valeur du dollar canadien. Les effets nets de l'appréciation du dollar canadien se sont avérés statistiquement et économiquement significatifs et négatifs pour l'emploi et les heures travaillées, et ses effets sont plus prononcés dans les industries davantage exposées au commerce international.

Finalement, le dernier chapitre s'intitule “Housing Market Dynamics and Macroprudential Policy”, dans lequel nous étudions la relation statistique suggérant un lien collatéral entre le marché immobilier and le reste de l'économique et si ce lien est davantage entraîné par des facteurs de demandes ou d'offres. Nous suivons également la littérature sur les chocs anticipés et examinons un cyle d'expansion-récession peut survenir de façon endogène la suite d'anticipations non-réalisées d'une hausse de la demande de logements. À cette fin, nous construisons un modèle néo-Keynésien au sein duquel le pouvoir d'emprunt du partie des consommateurs est limité par la valeur de leur patrimoine immobilier. Nous estimons le modèle en utilisant une méthode Bayésienne avec des données canadiennes. Nous évaluons la capacité du modèle à capter les caractéristiques principales de la consommation et du prix des maisons. Finalement, nous effectuons une analyse pour déterminer dans quelle mesure l'introduction d'un ratio prêt-à-la-valeur contracyclique peut réduire l'endettement des ménages et les fluctuations du prix des maisons comparativement à une règle de politique monétaire répondant à l'inflation du prix des maisons. Nous trouvons une relation statistique suggérant un important lien collatéral entre le marché immobilier et le reste de l'économie, et ce lien s'explique principalement par des facteurs de demande. Nous constatons également que l'introduction de chocs anticipés peut générer un cycle d'expansion-récession du marché immobilier, la récession faisant suite aux attentes non-réalisées par rapport à la demande de logements. Enfin, notre étude suggère également qu'un ratio contracyclique de prêt-à-la-valeur est une politique utile pour réduire les retombées du marché du logement sur la consommation par l'intermédiaire de la valeur garantie.

Mots-clés : Politique monétaire, Politique macroprudentielle, Chocs antici-

pés, Biens durables, Co-mouvement sectoriel, Fluctuations du taux de change, Ajustements du marché du travail, Estimation des données de panel, Cointégration des données de panel, Prêts hypothécaires.

Abstract

Economic fluctuations represent the movements of economic growth. It may experience acceleration phases (expansion) or deceleration (recession), and even depression if the decline in production is persistent. Economic fluctuations are related to differences between actual growth and potential growth. They can be explained by supply and demand shocks, as well as by the credit cycle. In the first case, the conditions of production are modified. This is the case when the price of production factors (wages, raw materials prices) or external factors influencing the price of products (exchange rate) evolve. Thus, an increase in the price of production factors causes a negative shock and slows growth. This slowdown may also be due to a negative demand shock caused by an increase in product prices caused by a currency appreciation, causing a decrease in exports. The second case concerns the financial variables and financial assets. Thus, in a period of expansion, economic agents borrow more and have speculative behaviors in response to anticipated supply and demand shocks. The value of securities and financial assets increases, causing a bubble that eventually burst, causing a collapse in the value of assets. Therefore, economic activity cannot be funded. This is what generates a recession, sometimes profound, as in the recent financial crisis.

This thesis includes three essays on macroeconomic fluctuations and economic cycles, specifically on the topics described above. The first chapter deals with expectations about monetary policy and on the reaction of econonomic agents on these expectations. A particular emphasis is placed on the consumption of durable goods and indebtedness related to this type of consumption. The second chapter discusses the influence of fluctuations in foreign exchange rates on labour demand in the Canadian manufacturing sector. Finally,

the third chapter focuses on spillover, sometimes negative, of the real estate market on household consumption and the impact on property prices and household debt of demand expectations in the property market.

The first chapter, entitled “Monetary Policy News Shocks and Durable Consumption”, provides insight on the link between durable goods spending and monetary policy news shocks. We propose and implement a new approach to identifying news shocks about future monetary policy. News shocks are identified recursively from the residuals of a monetary policy rule estimated using U.S. multi-horizon survey data. We then use those inferred news shocks in a structural VAR (SVAR). An expected monetary policy tightening leads to an increase in output, non-durable and durable goods consumption, and real price of durable goods. Although news shocks account for a significant fraction of output and consumption fluctuations, they contribute less than surprise shocks to economic fluctuations. We then carry out theoretical analysis using a dynamic stochastic general equilibrium (DSGE) model with durable goods and nominal rigidities. Results indicate that a model with sticky durable goods price can reproduce the positive correlation between the response functions of durable and non-durable goods consumption to policy news shocks that was found from the SVAR.

The second chapter is entitled “Exchange Rate Fluctuations and Labour Market Adjustments in Canadian Manufacturing Industries”. In this chapter, we estimate the impact of exchange rate fluctuations on hours worked and jobs in Canadian manufacturing industries. The analysis is based on a dynamic model of labour demand and the econometric strategy employs a panel two-step approach for cointegrating regressions. Our data is drawn from a panel of 20 manufacturing industries, from Statistics Canada’s KLEMS database, and covers a long sample period that includes two full exchange rate appreciation and depreciation cycles. We find that exchange rate fluctuations have economically and statistically significant effects on the labour decisions of Canadian manufacturing employers, and that these effects are stronger for trade-oriented industries.

Finally, the last chapter, entitled “Housing Market Dynamics and Macroprudential Policy", studies the statistical evidence suggesting a collateral link between the housing market and the rest of the economy and if the link is more demand- or supply-driven. We also followed the *news shocks* literature and look if a housing-market boom-bust can arise endogenously following unrealized expectations of a rise in housing demand. To this end, we construct a New Keynesian model in which a fraction of households borrow against the value of their houses. We estimate the model with Canadian data using Bayesian methods. We assessed the model's ability to capture key features of consumption and house price data. Finally, we performed an analysis to determine how well the introduction of a countercyclical loan-to-value (LTV) ratio can reduced household indebtedness and housing price fluctuations compare to a monetary policy rule augmented with house price inflation. We find statistical evidence suggesting an important collateral link between the housing market and the rest of the economy, and this link is mainly driven by demand factors. We also find that the introduction of news shocks can generate a housing market boom-bust cycle, the bust following unrealized expectations on housing demand. Finally, our study also suggests that a countercyclical loan-to-value ratio is a useful policy to reduce the spillover from housing market to consumption via the collateral value.

Keywords : Monetary Policy, Macroprudential Policy, News Shocks, Durable Goods, Sectoral Comovement, Exchange Rate Fluctuations, Labour Market Adjustments, Panel Data Estimation, Panel Cointegration, Mortgage Loans.

Table des matières

Liste des tableaux

Liste des figures

Remerciements

J'ai réalisé ce travail grâce à l'appui de nombreuses personnes qui m'ont aidé directement ou indirectement. La liste de ces personnes ne sera jamais exhaustive.

Je tiens à remercier mon directeur de recherche, Francisco Ruge-Murcia, pour tout ce qu'il m'a enseigné, ses conseils ainsi que pour sa patience. À chaque étape de ma thèse, il a su me faire me guider et me faire évoluer. Mes remerciements sont aussi adressés au professeur Gérard Gaudet, qui a su m'accorder sa confiance et sans qui mes études doctorales n'auraient pas été possible. Je voudrais remercier mon co-auteur Kevin Moran, avec qui j'ai eu d'excellente discussion et une excellente collaboration au cours de la rédaction de notre document de recherche.

Je remercie les laboratoires de recherche et les institutions qui m'ont accueillit et financé : le département de sciences économiques de l'Université de Montréal, tout spécialement son corps professoral, le Centre Interuniversitaire de Recherche en Economie Quantitative (CIREQ), et la Banque du Canada. Je suis également redevable aux participants des différentes conférences, séminaires, groupes de travail, où ces travaux ont été présentés, pour leurs discussions et commentaires.

Enfin, pour leur soutien et leurs encouragements, mes remerciements vont à l'endroit de ma famille et de mes amis. Mes parents m'ont toujours expliqué l'importance de l'éducation et d'avoir une excellente formation professionnelle. Finalement, une pensée toute spéciale va à mon épouse, qui m'a fournit un incroyable soutien au cours de toutes ces années.

À Amélie, Emmanuelle et Corinne.

Première partie

Thèse

Introduction générale

Les fluctuations économiques représentent les mouvements de la croissance économique. Celle-ci peut connaître des phases d'accélération (expansion) ou de ralentissement (récession), voire même de dépression si la baisse de production est persistente. Les fluctuations économiques sont liées aux écarts entre croissance effective et croissance potentielle. Elles peuvent s'expliquer par des chocs d'offre et demande, ainsi que par le cycle du crédit. Dans le premier cas, les conditions de la production se trouvent modifiées. C'est le cas lorsque le prix des facteurs de production (salaires, prix des matières premières) ou que des facteurs externes influençant le prix des produits (taux de change) évolue. Ainsi, une hausse du prix des facteurs de production provoque un choc négatif et ralentit la croissance. Ce ralentissement peut être également dû à un choc de demande négatif provoqué par une hausse du prix des produits causée par une appréciation de la devise, engendrant une diminution des exportations. Le deuxième cas concerne les variables financières et les actifs financiers. Ainsi, en période d'expansion, les agents économiques s'endettent et ont des comportements spéculatifs en réaction à des chocs d'offre ou demande anticipés. La valeur des titres et actifs financiers augmente, provoquant une bulle qui finit par éclater et provoquer un effondrement de la valeur des biens. Dès lors, l'activité économique ne peut plus être financée. C'est ce qui génère une récession, parfois profonde, comme lors de la récente crise financière.

Cette thèse inclut trois essais sur les fluctuations macroéconomiques et les cycles économiques, plus précisément sur les thèmes décrit ci-dessus. Le premier chapitre s'intéresse aux anticipations sur la politique monétaire et sur la réaction des agents écononomiques face à ces anticipations. Une emphase particulière est mise sur la consommation de biens durables et l'endettement relié à ce type de consommation. Le deuxième chapitre aborde la question de l'influence des variations du taux de change sur la demande de travail dans le secteur manufacturier canadien. Finalement, le troisième chapitre s'intéresse aux retombées économiques, parfois négatives, du marché immobilier sur la consommation des ménages et aux répercussions sur le prix des actifs immobiliers et sur l'endettement des ménages d'anticipations sur la demande dans le marché immobilier.

Le premier chapitre de cette thèse, intitulé "Monetary Policy News Shocks and Durable Consumption", s'intéresse aux anticipations sur la politique monétaire et sur la réaction des agents écononomiques face à ces anticipations. Plus précisément, il étudie, à l'aide de l'analyse de modèles autorégressifs vectoriels (ARV) et d'un modèle d'équilibre général dynamique stochastique (EGDS), les effets de chocs monétaires anticipés sur la consommation de biens durables. Pour ce faire, nous proposons une approche permettant d'extraire les chocs anticipés de données d'un sondage américain multi-horizon. Il est reconnu dans la littérature que les chocs monétaires anticipés et non-anticipés ont un impact sur des variables macroéconomiques clés tel que la production, les taux d'intérêt et l'inflation. Il est essentiel pour les banques centrales d'avoir une bonne compréhension de ces interactions lorsque vient le temps de prendre des décisions ou faire des annonces quant à leur politique monétaire. Toutefois, malgré la grande influence des taux d'intérêt sur la consommation de biens durables, peu d'études ont à ce jour porté sur les effets des chocs anticipés sur cette variable macroéconomique.

L'analyse des chocs monétaires anticipés est complexe. Alors que les effets des chocs non-anticipés ont souvent été mesurés à l'aide d'ARV ou de modèles néo-keynésiens, on a rarement tenté de mesurer les effets des chocs anticipés. Milani and Treadwell (2011) ont trouvé, à l'aide d'un modèle néo-keynésien de référence, que les effets des chocs non-anticipés sur la production tendent à être plus petits et de plus courte durée lorsque les chocs monétaires inclus une composante anticipée. Par ailleurs, les chocs anticipés ont des effets plus importants et persistants sur la production et l'inflation, quoique retardés. D'autres auteurs, tel que Lambertini et al. (2010a), Lambertini et al. (2011), et Gomes and Mendicino (2011), utilisent également un EGDS pour étudier les effets des chocs anticipés, cette fois avec une emphase sur les dynamiques du marché du logement. Ils concluent qu'une expansion monétaire anticipée peut générer des cycles d'expansion et de récession dans le marché du logement en augmentant temporairement la demande. Toutefois, aucune de ces études ne vérifie si leur modèle suivent bien les faits stylisés. Elles font plutôt l'hypothèse que leurs réponses théoriques, qui correspondent bien aux faits stylisés suivant un choc monétaire non-anticipé, reflètent également les réponses aux chocs anticipés. Si cette hypothèse s'avérait être non fondée, elle pourrait mener à des décisions ou des annonces monétaires inefficaces.

Une des causes possibles de cette lacune est la difficulté à extraire les chocs anticipés dans un modèle ARV structurel (ARVS). Le secteur privé consacre beaucoup d'efforts, à partir d'indications fournies par les banques centrales et d'annonces de nature économique, à la prévision de la politique monétaire, mais les économètres ne peuvent pas observer ces anticipations. Tel qu'abordé par Leeper et al. (2008) et Leeper and Walker (2011), cette asymétrie de l'information peut causer un problème d'inversibilité dans l'ARV estimé par l'économètre. Une non-inversibilité survient lorsque d'importantes variables d'état d'un modèle économique dynamique ne sont pas observées par l'économètre estimant l'ARV. L'impossibilité pour l'économètre d'observer le vecteur d'état dans son entièreté peut créer un écart entre les innovations de l'ARVS et les chocs économiques, ce qui pourrait invalider les conclusions tirées à partir de l'analyse des fonctions de réponses structurelles.

Dans le premier chapitre, nous proposons et mettons en application une nouvelle approche afin d'identifier des chocs monétaires anticipés et non-anticipés. Ces chocs sont identifiés de façon récursive à partir de données de sondage multi-horizon américaines : ce sont les résidus d'une politique monétaire de type Taylor. Nous étudions ensuite, à l'aide d'un ARVS, l'impact de ces chocs sur la consommation de biens durables et d'autres variables macroéconomiques. Finalement, en se servant des résultats du ARV comme référence, nous développons et calibrons un modèle EGDS néo-keynésien standard avec chocs monétaires et consommation de biens durables et non-durables afin de démêler les effets des chocs anticipés et non-anticipés.

Dans la première partie du chapitre, nous estimons deux modèles de politique monétaire à l'aide d'un filtre de Kalman. Pour ce faire, nous utilisons, comme approximation des attentes des agents, les prévisions multi-horizon de variables économiques américaines tirées du Survey of Professional Forecasters. Cela nous permet d'extraire de manière récursive, à partir du bruit de processus du filtre de Kalman, les éléments anticipés et non-anticipés des chocs monétaires. Certains résultats ressortent du lot. Premièrement, les éléments non-anticipés des chocs monétaires ont le plus grand écart-type, soit de deux à sept fois celui des chocs monétaires anticipés, et sont les principaux responsables de l'incertitude quant à la politique monétaire. Deuxièmement, lorsqu'estimée pour plusieurs sous-échantillons, la variance des éléments non-anticipés est celle qui varie le plus.

Dans un deuxième temps, nous estimons les effets dynamiques des chocs monétaires en utilisant un ARVS. Puisque nous utilisons les chocs monétaires identifiés dans la première partie du chapitre dans le modèle, nous évitons le problème d'inversibilité abordé précédemment. Les résultats obtenus avec cette méthode se distinguent de ceux trouvés à partir de modèles EGDS dans la littérature récente. En effet, les résultats obtenus avec les deux approches montrent qu'un resserrement inattendu de la politique monétaire a un effet retardé et négatif sur la production et un impact immédiat et négatif sur la consommation de biens durables. Toutefois, les résultats concernant les chocs anticipés obtenus à partir de notre ARVS font état d'une plus grande variété de schémas. Bien que les chocs monétaires anticipés un trimestre en avance ont un impact immédiat et négatif sur la consommation de biens durables et non-durables, les chocs anticipés de deux à quatre trimestres à l'avance causent quant à eux une hausse du produit intérieur brut et de la consommation des biens durables et non-durables.

Finalement, nous développons et calibrons un modèle EGDS avec rigidité dans les prix comprenant la consommation de biens durables et non-durables et intégrant des chocs monétaires anticipés. Notre modèle considère deux types d'agents : les prêteurs, qui agissent comme des agents consommant leur revenu permanent, et les emprunteurs, dont le crédit est contraint. Le but de ce modèle est de séparer les effets des chocs anticipés de ceux des chocs non-anticipés. Il est en mesure de répliquer deux résultats importants de la deuxième partie du chapitre, soit une augmentation immédiate de la demande de biens durables suite à un choc monétaire anticipé et un co-mouvement entre la consommation de biens durables et non-durables. Un des principaux résultats obtenus avec ce modèle est que, en présence de rigidité dans les prix, les firmes baissent leurs prix suite à un choc monétaire anticipé, car elles anticipent une baisse future du coût marginal causée par une baisse de la production. Cela a pour effet une hausse immédiate de la demande pour les deux types de biens.

Le second chapitre de cette thèse s'intitule "Exchange Rate Fluctuations and Labour Market Adjustments in Canadian Manufacturing Industries" et aborde la question de l'influence des variations du taux de change sur la demande de travail dans le secteur manufacturier canadien. Historiquement, l'influence du taux de change sur les industries manufacturières canadiennes a suscité beaucoup d'intérêt et la récente période d'appréciation soutenue du dollar canadien par rapport au dollar américain ne fait pas exception à la règle. La réponse du marché du travail à cette appréciation a particulièrement attiré l'attention, car plusieurs on craint qu'un dollar canadien fort cause une baisse de l'emploi dans le secteur manufacturier sur une période prolongée.

En comparant l'évolution de la valeur réelle du dollar canadien au nombre total d'heures travaillées dans le secteur manufacturier, ces craintes semblent fondées. La valeur réelle du dollar canadien a connu des cycles prononcés de dépréciations et d'appréciations au cours des 40 dernières années. Ces cycles semblent être négativement corrélés au nombre d'heures travaillées dans le secteur manufacturier. Par exemple, les années 1990 sont marquées par une dépréciation soutenue du dollar canadien qui a atteint son creux en 2002 et, tout au long de cette période, le nombre d'heures travaillées dans le secteur manufacturier a augmenté. À l'inverse, la période plus récente a connu une appréciation rapide de la devise, ainsi qu'une diminution importante du nombre d'heures travaillées.

Le deuxième chapitre présente une analyse quantitative du lien entre les fluctuations de taux de change et le travail dans les industries manufacturières. Plus précisément, nous tentons d'expliquer les effets à long terme des changements du taux de change sur le nombre d'emplois et d'heures travaillées dans le secteur manufacturier, ainsi que la vitesse à laquelle ces ajustements surviennent. Afin de répondre à ces questions, nous proposons un modèle dynamique de demande de travail que nous estimons à partir de données KLEMS, une base de données de panel par industrie organisée autour du Système de classification des industries de l'Amérique du Nord (SCIAN). Les données utilisées dans notre modèle vont de 1961 à 2008 et couvrent tous les changements majeurs dans la valeur réelle de la devise canadienne au cours des 50 dernières années.

Nous expliquons quatre principaux résultats. Tout d'abord, les variations de taux de change ont un effet considérable sur le nombre d'heures travaillées et sur le nombre d'emplois dans les industries manufacturières canadiennes. Lorsque la spécification de notre modèle préféré est utilisée, une appréciation de 10 points de pourcentage du dollar canadien est associée à une réduction de 3 pourcent du nombre d'heures travaillées et à une diminution de près de 3 pourcent du nombre d'emplois. Deuxièmement, ces ajustements se font assez lentement : à chaque année, seulement 13 pourcent de l'écart entre le niveau travail réel et le niveau ciblé est comblé. Troisièmement, les effets des variations du taux de change sont plus importants lorsque l'industrie a une forte exposition au commerce international. Quatrièmement, des changements importants au paysage institutionnel, notamment la mise en oeuvre de deux accords de libre-échange majeurs entre le Canada et ses partenaires commerciaux nord-américains, ont eu des impacts négatifs majeurs sur le niveau de travail dans les industries manufacturières canadiennes

Une étude antérieure semblable à la nôtre est celle de Leung and Yuen (2007), qui se penche également sur l'impact des variations de taux de change sur le niveau de travail dans les industries manufacturières canadiennes. Toutefois, notre étude se distingue de celle de Leung and Yuen (2007) sur deux points importants. Premièrement, nous utilisons un échantillon qui est considérablement plus long (1961-2008) que celui utilisé par les deux auteurs (1981-1997). Notre analyse couvre donc tous les changements importants dans la valeur externe du dollar canadien survenus durant l'ère moderne. Deuxièmement, notre plus grand échantillon nous permet d'utiliser une méthodologie économétrique se concentrant sur les ajustements à long terme du secteur manufacturier suite aux variations de taux de change. En effet, nous commençons par estimer la relation de cointégration entre le niveau de travail des industries manufacturières, le taux de change effectif réel et d'autres variables économiques. Lorsque le vecteur de cointégration est obtenu, nous évaluons la vitesse à laquelle les ajustements du travail s'effectuent afin de parvenir au niveau de long terme. De leur côté, Leung and Yuen (2007) font abstraction des ajustements de long terme et n'utilisent pas des techniques de cointégration.

Parmi les autres études semblables à la nôtre se trouve celle de Campa and Goldberg (2001), qui se penche sur les ajustements des industries manufacturières américaines aux fluctuations du dollar américain, mais qui ne trouve pas d'impact significatif sur l'emploi et le nombre d'heures travaillées. Ces résultats divergent de ceux de Dekle (1998), qui rapporte les effets importants des variations dans la valeur externe du yen sur l'emploi dans le secteur manufacturier japonais. Burgess and Knetter (1998), qui ont étudié un ensemble de pays industrialisés, concluent que les variations de taux de change ont un très faible impact sur les emplois manufacturiers de certain pays telles la France et l'Allemagne, mais qu'ils ont un effet prononcé dans d'autres pays comme les États-Unis, le Canada et le Royaume-Uni. Toutefois, aucune de ces études n'utilisent d'outil économétriques permettant de prendre en compte la cointégration de variables et d'identifier les ajustements à long terme.

Finalement, le dernier chapitre de cette thèse s'intitule “Housing Market Dynamics and Macroprudential Policy” et s'intéresse aux retombées économiques, parfois négatives, du marché immobilier sur la consommation des ménages et aux répercussions sur le prix des actifs immobiliers et sur l'endettement des ménages d'anticipations infondées sur la demande dans le marché immobilier. La corrélation entre les dépenses de consommation et le prix des maisons au cours des cycles économiques est bien documentée dans les études macroéconomiques. En effet, des estimations basées sur des séries chronologiques pour une variété de pays, dont le Canada, ont montré que les deux variables tendent à bouger ensemble. Il est important pour les décideurs politiques de bien comprendre les dynamiques entre le prix des maisons et l'accroissement de la dette des ménages, car il a été démontré que les bulles immobilières précédées d'une forte hausse de la dette des ménages tendent à causer des récessions plus profondes (IMF, 2012). L'un des cas les plus connu est la crise survenue aux États-Unis dans les années 2000 : le niveau élevé de dette des ménages, combiné à une baisse des critères de souscription d'emprunt hypothécaire et des attentes exubérantes quant à la hausse future de la valeur des maisons, a exposé le système financier américain un renversement soudain des marchés immobiliers. Une fois l'exubérance de l'immobilier partie, la baisse du prix des maisons et l'augmentation du nombre de défauts de paiements hypothécaires qui a résulté ont mis en danger le bilan financier des institutions financières qui étaient exposées directement ou indirectement au marché immobilier. Les retombées économiques découlant de cette crise financières furent également plus pénibles et longues que celle d'une récession typique, les ménages et les institutions financières s'étant engagées dans un long processus de désendettement suite à la crise. Durant la même période, le Canada a aussi connu une hausse significative du prix des maisons, des prêts hypothécaires et du crédit à la consommation. Le prix des maisons a doublé et les ratios du prix des maisons aux revenus et du prix des maisons aux loyers ont fortement augmenté (IMF, 2013). Le crédit hypothécaire a cru d'environ 9 pourcent par année entre 2000 et 2008, alors que l'endettement des ménages en pourcentage du revenu disponible est passé de 100 pourcent en 2000 à 165 pourcent en 2013. Par conséquent, on estime que les prêts hypothécaires et les prêts garantis par des biens immobiliers (principalement des marges de crédit hypothécaires) comptent pour 80 pourcent de la dette des ménages et 35 pourcent des actifs des banques, soit la plus grande exposition au risque des banques canadiennes. Par conséquent, plusieurs analystes croient que le boom immobilier au Canada est le principal risque à la stabilité financière du pays.

Le but du troisième chapitre a deux volets. D'une part, nous étudions l'importance de la relation entre les hausses du prix des maisons et les hausses de dépenses qui s'effectue grâce à une amélioration de la capacité d'emprunt des ménages. Plus spécifiquement, nous tentons de déterminer si la relation entre le marché immobilier et le reste de l'économie est statistiquement significative et, si c'est le cas, est-ce cette relation est dûe à des facteurs de demande ou d'offre. Nous suivons également la littérature portant sur les chocs anticipés et tentons de déterminer si des cycle d'expansion et de récession peuvent être produits de façon endogène suite à une anticipations infondées d'augmentation de la demande de maisons. Pour ce faire, nous élaborons un modèle néo-keynésien dans lequel une fraction des ménages emprunte en mettant en garantie leur maison. Nous estimons ce modèle à l'aide de données canadiennes par des méthodes Bayesiennes. Par la suite, nous tentons de déterminer à quel point l'instauration d'un ratio prêt-à-la-valeur contracyclique est efficace pour réduire l'endettement des ménages et les fluctuations du prix des maisons par rapport à une règle de politique monétaire répondant à l'inflation du prix des maisons.

Notre étude s'apparente à la littérature portant sur le rôle des contraintes d'endettement dans la transmission des chocs. Une des principales caractéristiques de ces modèles est que la contrainte d'endettement sert de mécanisme de propagation plutôt que de moteur de fluctuations macroéconomiques comme tel. Parmi ces études, nous retrouvons celle de Iacoviello and Neri (2010), qui, à l'aide de séries chronologiques américaines, estime un modèle néo-keynésien et se penche sur les sources et les conséquences des fluctuations enregistrées dans le marché de l'immobilier américain. Les résultats qui y sont présentés portent à croire que de lents progrès technologiques dans le secteur de l'habitation seraient à l'origine de la tendance à la hausse du prix réel des maisons depuis 40 ans et que les retombées du marché de l'immobilier, qui ne sont pas négligeables, sont concentrées sur la consommation plutôt que sur les investissements des entreprises et sont devenues de plus en plus importantes avec le temps. Lambertini et al. (2010b) analysent les cycles d'expansion et de récession dans le marché de l'immobilier en fonction des changements des attentes des ménages. Ils concluent qu'en présence de rigidité des prix et des salaires, les attentes par rapport à la conduite de la politique monétaire et à la productivité future peuvent générer dans le secteur de l'immobilier des cycles d'expansion et récession similaires à ceux trouvés dans les résultats empiriques. Finalement, Gelain et al. (2013) trouvent que l'adoption par une fraction des agents d'une simple règle de prévision basées sur une moyenne mobile (c'est-à-dire une déviation de l'hypothèse d'anticipations rationnelles des agents) peut amplifier la volatilité et la persistence du prix des maisons comparativement à des modèles similaires basés sur des anticipations complètement rationnelles.

Notre modèle a plusieurs caractéristiques en commun avec celui de Iacoviello and Neri

(2010). Au coeur du modèle se trouve un système de prêts entre les ménages tel que dévelopé par Kiyotaki and Moore (1997). Il y a deux types de ménages qui se distinguent par le degré auquel ils actualisent le futur. À l'équilibre, l'un des types de ménages est prêteur, alors que l'autre est emprunteur. Les emprunteurs font face à une contrainte d'endettement qui limite leur capacité à emprunter à une fraction de la valeur de leurs maisons. Une augmentation de la valeur des maisons peut par conséquent améliorer la capacité d'emprunt des emprunteurs, ce qui leur permet d'accroître leur consommation. Les ménages achètent et vendent leurs maisons sur un marché central.

Puisque notre but est de quantifier les relations entre la consommation et le niveau du prix de maison au Canada, nous estimons notre modèle à l'aide de données canadiennes par des méthodes Bayesiennes. Pour ce faire, nous reprennons le modèle de Iacoviello and Neri (2010), que nous developpons d'avantage à deux niveaux. Tout d'abord, nous introduisons des prêts multi-périodes à taux fixe. Au niveau théorique, les EGDS avec un secteur des maisons comme celui de Iacoviello and Neri (2010) font généralement abstraction des prêts multi-périodes et font l'hypothèse de prêts sur une prériode à taux variable. Étant donné que la durée médiane des contrats hypothécaires au Canada est de 5 ans et que la plupart d'entre eux sont à taux fixe, ces caractéristiques pourraient s'avérer nécessaires pour reproduire les faits stylisés des cycles économiques et évaluer l'efficacité des politiques macroprudentielles. Deuxièmement, nous avons calibré le ratio de ménages patients aux ménages impatients afin qu'il reflète les données sur la richesse et la distribution des revenus. Une calibration qui sous-estimerait le pourcentage de ménages impatients aurait pour effet de sous-estimer à la fois le ratio de la dette au PIB et l'effet multiplicateur de changements de politiques macroprudentielles sur l'ensemble de l'économie.

Notre analyse empirique révèle qu'il existe une relation importante entre l'appréciation du prix des maisons et le reste de l'économie et que cette dynamique est principalement dû à des facteurs de demande. Nous trouvons également que l'ajout de chocs anticipés peut générer un cycle d'expansion et de récession dans le marché des maisons, la récession survenant après que des anticipations sur la demande se soient avérées infondées.

Le deuxième objectif du troisième chapitre porte sur les politiques macroprudentielles, tout spécialement le ratio de prêts-à-la-valeur (RPV). Adopté afin d'atténuer les accumulations de risque dans le secteur de l'immobilier, le RPV impose un plafond à la taille du prêt hypothécaire par rapport à la valeur de la propriété, ce qui a pour effet d'instaurer une mise de fond minimale obligatoire. On considère que le RPV peut atténuer les cycles d'expansion et récession en contrôlant à la fois le crédit et les anticipations et en améliorant la résilience des institutions financières : en limitant le RPV, il est possible de reserrer la contrainte de liquidité des emprunteurs ciblés et de limiter la demande dans certains segments du marché de l'immobilier (et vice-versa dans le cas de récession). Ceci a pour effet de modifier les attentes du marché et les incitatifs à la spéculation qui jouent un rôle clé dans la dynamique des bulles immobilières.

Notre étude s'apparente à quelques courants de la littérature. Tout d'abord, certains articles prennent compte des effets de la politique monétaire et/ou des changements dans la réglementation des RPV dans le contexte d'un modèle EGDS similaire à ceux de Iacoviello (2005) et Iacoviello and Neri (2010). Parmi ceux-ci, nous retrouvons Christensen et al. (2009), Kannan et al. (2012), Justiniano et al. (2013), Lambertini et al. (2013), Gelain et al. (2013), et Gelain et al. (2014). Lambertini et al. (2013) étudient les gains potentiels liés à l'adoption de politiques monétaire ou macroprudentielles basées sur le cycle du prix des maisons et du crédit. Ils concluent qu'il est essentiel, lorsque l'adoption de mesures portant à la fois sur les taux d'intérêt et sur le RPV sont permises, de prendre en compte les implications de l'hétérogenéité du bien-être afin d'optimiser l'efficacité de celles-ci. Finalement, Gelain et al. (2014) rapportent qu'une politique monétaire est moins efficace lorsque les contrats sont multi-périodes, mais uniquement lorsqu'ils s'agit de prêts hypothécaires à taux fixe ou lorsqu'on ne peut pas forcer les emprunteurs à rembourser leurs prêts plus rapidement.

Notre étude révèle que des RPV plus élevés peuvent amplifier les cycles d'expansion et récession en favorisant les investissements immobiliers spéculatifs des emprunteurs dont le crédit est limité et que cet effet est surtout dû la valeur des propriétés mises en garantie. Toutefois, le RPV ne semble pas avoir d'impact significatif sur les dynamiques agrégées du prix des maisons, ce qui est conforme à d'autres modèles EGDS avec contrainte de crédit pour les emprunteurs élaborés par Iacoviello (2005) et Kiyotaki et al. (2010).

Chapter 1

Monetary Policy News Shocks and Durable Consumption

1.1 Introduction

This chapter studies the effect of monetary policy news shocks (i.e., anticipated shocks) on consumption of durable goods, using both vector autoregressive (VAR) analysis and a dynamic stochastic general equilibrium (DSGE) model. The empirical analysis is possible thanks to our proposed approach to retrieving news shocks from U.S. multi-horizon survey data. There is a widespread agreement in the literature that anticipated and unanticipated monetary policy shocks have an impact on key macroeconomic variables such as output, interest rate and inflation, and it is crucial for central bankers to have a good understanding of these interactions when making monetary policy decisions or announcements. However, despite the strong impact of interest rates on durable goods consumption, little attention has been paid so far to the effect of news shocks on this macroeconomic indicator.

Analyzing the effect of anticipated monetary policy shocks is challenging. While the effects of unanticipated shocks have often been measured through VARs and New Keynesian models, only a few attempts have been made to study the effects of anticipated shocks. Milani and Treadwell (2011) have found, in a benchmark New Keynesian model, that unanticipated shocks tend to lead to smaller and more short-lived responses of output when monetary shocks are assumed to include an anticipated component. In contrast, anticipated shocks have a larger, delayed and more persistent effect on output and inflation. Other authors such as Lambertini et al. (2010a), Lambertini et al. (2011), and Gomes and Mendicino (2011) also use a DSGE to study the impact of anticipated shocks, with a focus on housing market dynamics. They find that expectations on the conduct of monetary policy can generate housing market boom-bust cycles by temporarily raising housing demand after an expected monetary expansion. However, none of these studies test whether their models describe well the stylized facts. Instead, they assume their theoretical responses, which describes well stylized facts following an unanticipated monetary policy shock, also reflect responses to anticipated shocks. If proven incorrect, this strong assumption could result in ineffective policy decisions or monetary policy announcements.

One possible explanation for this shortcoming is the difficulty to retrieve news shocks in a structural vector autoregression (SVAR) model. The private sector employs significant resources to anticipate, based on direction provided by central banks and economic announcements, future policy monetary decisions, but the econometrician cannot observe these anticipations. This asymmetry of information can bring into the econometrician's estimated VAR the invertibility problem identified by Leeper et al. (2008) and Leeper and Walker (2011). Non-invertibility arises when important state variables from a dynamic economic model are unobserved by an econometrician estimating a VAR. The impossibility for the econometrician to observe the full state vector may create a gap between the VAR innovations and the economic shocks, potentially invalidating the conclusions drawn from structural impulse response analysis.

In this chapter, we propose and implement a new approach to identifying anticipated and unanticipated monetary policy shocks. These shocks are identified recursively as residuals from a Taylor-type monetary policy rule using U.S. multi-horizon survey data. We then study the impact of these news shocks on durable goods consumption and other macroeconomic variables by estimating a SVAR. Finally, using the results from the VAR as a benchmark, we develop and calibrate a standard New Keynesian DSGE model with durable and non-durable goods consumption and monetary policy shocks to disentangle the effects of anticipated and unanticipated shocks.

In the first part of the chapter, we estimate two monetary policy models through Kalman filtering. To do so, we use multi-horizon forecasts of U.S. economic variables from the Survey of Professional Forecasters as proxies for agents' expectations. This allows us to retrieve recursively the anticipated and unanticipated components of monetary policy shocks from the Kalman filter process noise. A few results stand out. First, the unanticipated component of monetary policy shocks has the highest standard deviation - nearly two to seven times the standard deviation of news shocks - and drives most of the monetary policy uncertainty. Second, when estimated on many subsamples, the variance of the unanticipated component displays the largest movements.

As a second step, we estimate the dynamic effects of monetary policy news shocks using a SVAR. Since we explicitly integrate the news shocks identified in the first part of the chapter in the model, we avoid the invertibility problem explained earlier. The results obtained through this method contrast with those obtained from DSGE models in recent literature. Under both approaches, an unanticipated monetary policy tightening is found to have a delayed and negative effect on output, and an immediate and negative impact on consumption of durable goods. However, the results obtained from our SVAR reveal that news shocks display more diverse patterns. While new shocks one quarter ahead have an immediate and negative impact on consumption of durable and non-durable goods, news shocks two to four quarters ahead induce an increase in real gross domestic product and consumption of real durable and non-durable goods.

Finally, we develop and calibrate a sticky price DSGE model with durable and non-durable goods that integrates news about future monetary policies. Our model features two types of agents: the lenders, who act as permanent income agents, and the borrowers, who are credit constrained. The objective of the model is to separate the effects of news shocks from those of unanticipated shocks. Our model captures two main features of the empirical findings from the second part of the chapter: the increase in durable goods demand on impact following an anticipated monetary shocks, and the co-movement between durable and non-durable goods consumption. The key insight is that, in the presence of sticky prices, firms lower their prices following an anticipated monetary policy shock, by anticipating a future decline in marginal cost due to a decrease in production. This yields an immediate increase in demand for both types of goods.

The chapter is organized as follows. Section 1.2 describes the monetary policy rule model and its estimation to recover news shocks. Section 1.3 presents VAR-based evidence on the response of durable goods consumption, non-durable goods consumption, real GDP and relative price of durable goods to these shocks. Section 1.4 develops and calibrates a two-agents DSGE model with non-durable and durable goods, sticky price and borrowing constraint, and illustrates the effects of introducing monetary policy news shocks on the dynamics of the model. Section 1.5 provides concluding remarks.

1.2 Recovering News Shocks

In this section, we propose an approach to recovering unanticipated and anticipated monetary policy shocks. To do so, we develop a model of agents' interest rate expectations, propose to use multi-horizon survey data as proxies for agents' expectations, and estimate the model using Kalman filter. Estimation results are then discussed.

1.2.1 Monetary Policy Rule and Agents' Expectations

Assume that the Federal Reserve decisions follow a linear, time-invariant rule of the form:

$$R_t = C + \rho_R R_{t-1} + \rho_\pi \left(\pi_t - \pi^*\right) + \rho_y \left(\hat{y}_t - \hat{y}^*\right) + \epsilon_t^0 + \epsilon_{t-1}^1 + \epsilon_{t-2}^2 + \epsilon_{t-3}^3 + \epsilon_{t-4}^4, \tag{1.1}$$

where C is a constant, R is the nominal interest rate, π is the gross inflation rate, π^* is the targeted gross inflation rate, $\hat{y}$ is the gross output growth rate, $\hat{y}^*$ is the gross potential output growth rate, ϵ_t^0 is the unanticipated component (surprise) of the monetary policy shock, and ϵ_{t-1}^1, ϵ_{t-2}^2, ϵ_{t-3}^3 and ϵ_{t-4}^4 are the anticipated component (news) of the monetary policy shock. All variables are in natural logarithm.[1]

Economic agents have in period t an information set Ω_t that goes beyond current and past realizations of ϵ^0, R, π and $\hat{y}$. More specifically, agents observe the current and past values of the monetary news shocks ϵ^1, ϵ^2, ϵ^3 and ϵ^4. The notation ϵ^j_{t-i}, $\forall i, j$, means that the anticipated disturbances (or news shocks) learnt in $t-i$ will affect the economy in j periods ahead (i.e. we learn in $t-i$ a news that will happen in $t-i+j$). More specifically, the disturbance ϵ^1_t represents an innovation to R_{t+1}, which is announced in period t but materializes only in period $t+1$. Note that ϵ^1_t does not appear in the expression for R_t given above. Rather, the above expression features ϵ^1_{t-1}, the one-period-ahead announcement made in period $t-1$. Similarly, ϵ^2_t, ϵ^3_t and ϵ^4_t are observed in t and represent two-, three-, and four-period-ahead announcements of future changes in the interest rate. However, there is an asymmetric information between economic agents and econometrician. While agents observe directly news shocks and incorporate this information in their expectations and decisions, these shocks and the expectations of the agents cannot be observed by the econometrician. We assume that multi-horizon survey data from the Survey of Professional Forecasters (SPF) are good approximation of the agents expectations, and therefore allows us to infer news shocks.

Unanticipated and anticipated components of the monetary policy shocks follow a multivariate normal distribution[2]:

$$\begin{bmatrix} \epsilon^0_t \\ \epsilon^1_t \\ \epsilon^2_t \\ \epsilon^3_t \\ \epsilon^4_t \end{bmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\epsilon^0} & 0 & 0 & 0 & 0 \\ 0 & \sigma^2_{\epsilon^1} & 0 & 0 & 0 \\ 0 & 0 & \sigma^2_{\epsilon^2} & 0 & 0 \\ 0 & 0 & 0 & \sigma^2_{\epsilon^3} & 0 \\ 0 & 0 & 0 & 0 & \sigma^2_{\epsilon^4} \end{pmatrix} \right]. \tag{1.2}$$

[1] We conducted some experiments with more flexible lag structures, including, among others, a backward looking rule instead of a current looking rule. Results under all specifications were quantitatively similar.

[2] Different specifications were estimated, among them one allowing for serial correlation among news shocks. Results were quantitatively similar.

Agents form interest rate expectations based on the known monetary policy rule and Ω_t. Their expectation of the interest rate in $t+1$ is therefore

$$E_t\left(R_{t+1}|\Omega_t\right) = C + \rho_R E_t\left(R_t|\Omega_t\right) + \rho_\pi E_t\left(\pi_{t+1} - \pi^*|\Omega_t\right) + \rho_y E_t\left(\hat{y}_{t+1} - \hat{y}^*|\Omega_t\right)$$
$$+ E_t\left(\epsilon^0_{t+1}|\Omega_t\right) + E_t\left(\epsilon^1_t|\Omega_t\right) + E_t\left(\epsilon^2_{t-1}|\Omega_t\right) + E_t\left(\epsilon^3_{t-2}|\Omega_t\right) + E_t\left(\epsilon^4_{t-3}|\Omega_t\right).$$

First note that $E_t\left(R_t|\Omega_t\right) = R_t$, and that $E_t\left(\epsilon^1_t|\Omega_t\right) = \epsilon^1_t$, $E_t\left(\epsilon^2_{t-1}|\Omega_t\right) = \epsilon^2_{t-1}$, $E_t\left(\epsilon^3_{t-2}|\Omega_t\right) = \epsilon^3_{t-2}$, and $E_t\left(\epsilon^4_{t-3}|\Omega_t\right) = \epsilon^4_{t-3}$ because information on anticipated monetary policy shocks is part of Ω_t. Also, since the unconditional expectation of the unanticipated shock is zero, $E_t\left(\epsilon^0_{t+1}|\Omega_t\right) = E\left(\epsilon^0\right) = 0$. Therefore, the agents' expectation in period t of the interest rate in $t+1$ is [3]

$$E_t\left(R_{t+1}\right) = C + \rho_R R_t + \rho_\pi E_t\left(\pi_{t+1} - \pi^*\right) + \rho_y E_t\left(\hat{y}_{t+1} - \hat{y}^*\right) + \epsilon^1_t + \epsilon^2_{t-1} + \epsilon^3_{t-2} + \epsilon^4_{t-3}. \quad (1.3)$$

Using the same logic, the agents' expectations in period t of the interest rate in $t+2$, $t+3$ and $t+4$ are

$$E_t\left(R_{t+2}\right) = C + \rho_R E_t\left(R_{t+1}\right) + \rho_\pi E_t\left(\pi_{t+2} - \pi^*\right) + \rho_y E_t\left(\hat{y}_{t+2} - \hat{y}^*\right) + \epsilon^2_t + \epsilon^3_{t-1} + \epsilon^4_{t-2}, \quad (1.4)$$

$$E_t\left(R_{t+3}\right) = C + \rho_R E_t\left(R_{t+2}\right) + \rho_\pi E_t\left(\pi_{t+3} - \pi^*\right) + \rho_y E_t\left(\hat{y}_{t+3} - \hat{y}^*\right) + \epsilon^3_t + \epsilon^4_{t-1}, \quad (1.5)$$

and

$$E_t\left(R_{t+4}\right) = C + \rho_R E_t\left(R_{t+3}\right) + \rho_\pi E_t\left(\pi_{t+4} - \pi^*\right) + \rho_y E_t\left(\hat{y}_{t+4} - \hat{y}^*\right) + \epsilon^4_t. \quad (1.6)$$

Monetary policy expectations can be divided into two components: (i) conditional expectations about the systematic part of the monetary policy rule, which are based on expectations of inflation and real output growth and the past values of the interest rate, and (ii) anticipated deviations from that systematic part of the rule, also called news

[3] In addition, to simplify the notation, all the expectations of $t+i$ for all i will be assumed conditional on the information set available in t, that is $E_{t+i}\left(\ldots\right) = E_{t+i}\left(\ldots|\Omega_{t+i}\right)$ for all i.

shocks.

As explained above, our baseline specification includes a numerical inflation target. This feature is based on results from a special edition of the Survey of Professional Forecasters (SPF)[4], which revealed that about half of the forecasters believe the Federal Reserve has a specific inflation target. However, the other half is of the view that the Federal Reserve does not use any numerical inflation target. For this reason, we also estimate a linear, time-invariant rule without any explicit target for gross inflation rate and real output growth:

$$R_t = C + \rho_R R_{t-1} + \rho_\pi \pi_t + \rho_y \hat{y}_t + \epsilon_t^0 + \epsilon_{t-1}^1 + \epsilon_{t-2}^2 + \epsilon_{t-3}^3 + \epsilon_{t-4}^4, \tag{1.7}$$

where the variables, the constant and the monetary policy shocks are defined in the same way as in the baseline specification. While equation (1.2) remains the same under this alternative specification, equations (1.3) to (1.6) have to be modified accordingly and yield

$$E_t\left(R_{t+1}\right) = C + \rho_R R_t + \rho_\pi E_t\left(\pi_{t+1}\right) + \rho_y E_t\left(\hat{y}_{t+1}\right) + \epsilon_t^1 + \epsilon_{t-1}^2 + \epsilon_{t-2}^3 + \epsilon_{t-3}^4, \tag{1.8}$$

$$E_t\left(R_{t+2}\right) = C + \rho_R E_t\left(R_{t+1}\right) + \rho_\pi E_t\left(\pi_{t+2}\right) + \rho_y E_t\left(\hat{y}_{t+2}\right) + \epsilon_t^2 + \epsilon_{t-1}^3 + \epsilon_{t-2}^4, \tag{1.9}$$

$$E_t\left(R_{t+3}\right) = C + \rho_R E_t\left(R_{t+2}\right) + \rho_\pi E_t\left(\pi_{t+3}\right) + \rho_y E_t\left(\hat{y}_{t+3}\right) + \epsilon_t^3 + \epsilon_{t-1}^4, \tag{1.10}$$

and

$$E_t\left(R_{t+4}\right) = C + \rho_R E_t\left(R_{t+3}\right) + \rho_\pi E_t\left(\pi_{t+4}\right) + \rho_y E_t\left(\hat{y}_{t+4}\right) + \epsilon_t^4. \tag{1.11}$$

1.2.2 Data

As mentioned above, because the econometrician is not able to observe anticipated policy shocks known by agents, there is asymmetric information. We propose to use forecast data from SPF as proxies for agent's expectations to infer those anticipated shocks.

The SPF is published each quarter by the Federal Reserve Bank of Philadelphia. It polls professional economists on their views about the economy over the next few quarters and

[4]Conducted in 2007Q4.

years, and provides individual, average and median forecasts of the nominal GDP, the GDP price index, corporate profits, the real GDP and its components, and a number of monthly business indicators, such as interest rates, housing starts, industrial production, and the consumer price index. On average, between 40 and 50 professional forecasters respond to the survey every quarter.

We assume professional forecasters have a root mean squared error loss function over their forecast horizon, and then have for objective to report an unbiased forecast for the eventual forecast users. Based on Patton and Timmermann (2007), this hypothesis allows us to focus our analysis on consensus (median) forecasts. Our empirical analysis is therefore based on the SPF median forecast of the quarterly 3-months Treasury-Bill rate[5], of the annualized quarterly rate of CPI inflation and of the annualized quarterly real GDP growth rate[6]. Since the forecast for the 3-months Treasury-Bill rate was added to the survey in the third quarter of 1981, our sample goes from that quarter to the fourth quarter of 2010.[7]

As mentioned in Section 1.2.1, about half of the forecasters who responded to the special SPF survey on the Federal Reserve monetary policy believe the central bank has a specific numerical target, of 1.75 percent on average, that is measured by the PCE or Core PCE. Given that the SPF database does not include forecasts of these measures for a sample of good length for estimation[8], we use forecasts of the closest inflation index available, the CPI.[9] In addition, we establish that the CPI target π^* is 1.75 percent.

Finally, the target for real GDP growth, $\hat{y}^*$, is determined by a linear trend.

[5]The Fed Funds rate is not part of the SPF.

[6]We conducted some experiments with annual inflation and GDP growth rates rather than annualized inflation and GDP growth rates. We found that there was no loss from a specification in first differences using annualized quarterly data, as results under all specifications were quantitatively similar.

[7]See Appendix 1.1 for details.

[8]The Core CPI, the PCE and the Core PCE were added to the survey in the first quarter of 2007.

[9]Estimation with the GDP deflator instead of the CPI yields quantitatively similar results, for both inferred news shocks and point estimates.

1.2.3 Estimating the Model

To infer policy shocks, both unanticipated and anticipated, we first estimate the monetary policy rule using Kalman filter. This process yields a measure of the deviations from the predicted policy, or process noise, which are the monetary policy shocks of our model.

The equation system of the baseline specification presented in Section 1.2.1, which includes equations (1.1), (1.3), (1.4), (1.5) and (1.6), and the distribution assumed in equation (1.2) can be casted into a state-space form of an explicit discrete time-invariant type. Assuming there is no measurement errors, the discrete time-invariant Kalman filter can be written in terms of a state equation

$$x_{t+1} = Ax_t + Cw_{t+1},$$

a measurement equation

$$y_t = Dx_t + Eu_t,$$

and a noise covariance matrix

$$E\left[w_t w_t'\right] = Q.$$

The vector x contains the hidden states, which are the policy shocks ϵ^0, ϵ^1, ϵ^2, ϵ^3 and ϵ^4, y is the vector of observables, which includes R, u is the control signals that includes π, π^*, $\hat{y}$, and $\hat{y}^*$, and, finally, w is the process noise which is assumed to be drawn from a zero-mean multivariate normal distribution with a covariance Q as in equation (1.2). The state equation is described by A, a state transition model applied to the previous state, and C, the noise model. The measurement equation is described by D, the observation model that maps the true state space into the observed space, and E, the control-input model that is applied to the control vector in the measurement equation. The initial state and the noise vector are all assumed to be mutually independent for all leads and lags. The alternative specification has the same structure, but with straightforward modifications. See Appendix 1.2 for explicit details on the form and elements of the vectors and matrices.

We assume policy shocks follow the predetermined structure presented in equations (1.1) to (1.6). This structure, common in news shocks literature, imposes a strong relationship in the expectations data. More specifically, agents keep updating their expectations of R in respect of a given period using information on all past and current policy shocks in respect of that period. For a simple exposition of the recursion implied by the structure of news shocks, assume that expectations of the interest rate for period $t+4$ only a linear function of policy shocks:

$$
\begin{aligned}
&E_t\left(R_{t+4}\right)=\epsilon_t^4, \\
&E_{t+1}\left(R_{t+4}\right)=\epsilon_t^4+\epsilon_{t+1}^3, \\
&E_{t+2}\left(R_{t+4}\right)=\epsilon_t^4+\epsilon_{t+1}^3+\epsilon_{t+2}^2, \\
&E_{t+3}\left(R_{t+4}\right)=\epsilon_t^4+\epsilon_{t+1}^3+\epsilon_{t+2}^2+\epsilon_{t+3}^1, \\
&E_{t+4}\left(R_{t+4}\right)=\epsilon_t^4+\epsilon_{t+1}^3+\epsilon_{t+2}^2+\epsilon_{t+3}^1+\epsilon_{t+4}^0.
\end{aligned}
$$

This feature allows us to retrieve recursively policy shocks using Kalman filter process noise. By identifying ϵ_t^4 in period t, we are able to recover ϵ_{t+1}^3 in period $t+1$, and iteratively, all news shocks in respect of R_{t+4}.

As mentioned above, we estimate the monetary policy rule by maximum likelihood using the Kalman filter. To do so, the *Active-Set* local optimization algorithm is used. Estimation results for three periods are reported in Table 1.1. The first column reports estimates for the entire sample (i.e. 1981Q3 to 2010Q4), the second column presents the estimation for the combined tenures of Paul Volcker and Alan Greenspan (i.e. 1981Q3 to 2006Q4), while the last column focuses on the tenure of Alan Greenspan only (i.e. 1987Q3 to 2006Q4).[10]

A number of interesting results stand out: (i) estimates are all significant at a 1 percent level[11], (ii) they are of the expected sign in both specifications and all subperiods,

[10]As robustness check, we estimated the equation system (1.1), (1.3), (1.4), (1.5) and (1.6) by restricted SURE method, justified by the fact that the disturbances are correlated. Results were quantitatively similar.

[11]Using numerical approximation to the Hessian of the log-likelihood built up by the optimization routine. These approximations are not guaranteed to be accurate and they are not robust to heteroscedasticity and serial correlation. The results obtained using a robust variance covariance matrix computed numerically, including a Newey-West style score covariance using two-sided derivatives, are quantitatively similar.

and (iii) the unanticipated component of monetary policy shocks has the highest standard deviation, between two to seven times the standard deviation of anticipated shocks. Although there are small differences between both specifications in the point estimates of ρ_π and ρ_y, this effect is normal given that we estimated the baseline specification in deviations from a target and the alternative specification in levels.[12] The estimate of the inflation target by the SPF forecasters, π^*, also explains some of the difference between the two specifications of ρ_π. The estimates of the standard errors of the unanticipated and anticipated components of the monetary policy shocks do not vary significantly between the two specifications, and all the vectors of estimated shocks (i.e. ϵ^0, ϵ^1, ϵ^2, ϵ^3 and ϵ^4) under both specifications have a Pearson coefficient of correlation between specifications of over 0.994. Finally, the estimates of the smoothing parameter ρ_r are high in all cases, suggesting considerable interest rate inertia: only 10 to 20 percent of the gap between the interest rate and its target is closed every period.

While we observe slight differences in the values of the point estimates between the two subperiods and the entire sample, the major differences are in the values of the standard errors of the monetary policy shocks. Comparing the full sample with the subsample estimates, we can conclude that deviations from the policy rule were more important during the period of Bernanke's tenure. Indeed, the standard error of the unanticipated component (or surprise shock) is nearly three to five times lower for the Volcker-Greenspan period than it is for the full sample, while the ones for the news shocks are between two and four times lower in the Volcker-Greenspan period than they are in the full sample.

[12]The estimated value for ρ_π is higher than previous studies, mainly because we estimate the model in ln, not in level. When we estimate the model in level, the results are closer to the one found in previous studies, but the estimated shocks remained similar.

Table 1.1: Estimation Results

Parameters[a]	Full Sample	Volcker-Greenspan[b]	Greenspan
Baseline Specification			
C	-0.4943	-0.3586	-0.3630
	(0.0272)	*(0.0324)*	*(0.0384)*
ρ_R	0.8391	0.8795	0.8818
	(0.0070)	*(0.0093)*	*(0.0110)*
ρ_π	2.8049	1.6976	2.3087
	(0.4037)	*(0.3325)*	*(0.4872)*
ρ_y	2.6838	2.5616	3.8130
	(0.4228)	*(0.2847)*	*(0.4065)*
σ_{ϵ^0}	0.0158	0.0051	0.0038
	(0.0021)	*(0.0007)*	*(0.0006)*
σ_{ϵ^1}	0.0054	0.0019	0.0018
	(0.0007)	*(0.0003)*	*(0.0003)*
σ_{ϵ^2}	0.0070	0.0013	0.0015
	(0.0009)	*(0.0002)*	*(0.0002)*
σ_{ϵ^3}	0.0038	0.0015	0.0016
	(0.0005)	*(0.0002)*	*(0.0003)*
σ_{ϵ^4}	0.0020	0.0010	0.0011
	(0.0003)	*(0.0001)*	*(0.0002)*
Log-likelihood	704.0035	887.6048	679.1685
Alternative Specification			
C	-0.6276	-0.4584	-0.5094
	(0.0340)	*(0.0366)*	*(0.0438)*
ρ_R	0.8396	0.8813	0.8829
	(0.0178)	*(0.0093)*	*(0.0109)*
ρ_π	2.7653	1.6308	2.3087
	(0.0070)	*(0.3317)*	*(0.4822)*
ρ_y	3.0719	2.7349	3.9938
	(0.4036)	*(0.2806)*	*(0.3985)*
σ_{ϵ^0}	0.0146	0.0048	0.0035
	(0.4205)	*(0.0007)*	*(0.0006)*
σ_{ϵ^1}	0.0052	0.0018	0.0018
	(0.0020)	*(0.0003)*	*(0.0003)*
σ_{ϵ^2}	0.0068	0.0013	0.0015
	(0.0007)	*(0.0002)*	*(0.0002)*
σ_{ϵ^3}	0.0038	0.0015	0.0016
	(0.0005)	*(0.0002)*	*(0.0003)*
σ_{ϵ^4}	0.0020	0.0010	0.0011
	(0.0003)	*(0.0001)*	*(0.0002)*
Log-likelihood	709.4609	893.6878	684.2855

[a] Standard errors are provided in parentheses.

[b] Although Paul Volcker's tenure starts in 1979, our sample starts in the third quarter of 1981.

1.3 The Effects of Monetary News Shocks on Durable Spending

In this section, we estimate the dynamic effects of monetary policy news shocks on durable spending using a vector autoregression (VAR) model. We first briefly present the VAR, the data and the identifying restrictions, and then discuss the empirical estimates.

1.3.1 VAR Specification and Identification

To assess the impact of an identified anticipated monetary policy shock on the market of durable goods, we estimate a vector autoregression (VAR) with block exogeneity restrictions for the U.S. economy specified as follows:

$$q_t = \sum_{i=1}^{p} G_i q_{t-i} + H z_t + e_t, \tag{1.12}$$

where q is a vector of variables of size $(n_x + n_y) \times 1$, containing, in that order, n_x exogenous variables x and n_y endogenous variables y. Variable z contains a constant and a linear time trend, while e is the contemporaneous disturbances. G_i is a $(n_x + n_y) \times (n_x + n_y)$ matrix of coefficients on the lagged values of q and H is a $(n_x + n_y) \times 2$ matrix of coefficients on deterministic regressors.

Let y be a $T \times 5$ matrix composed of the following $T \times 1$ vectors of endogenous variables (in this order): (i) real GDP, (ii) real durable goods consumption, (iii) real price of durable goods, (iv) the CPI, and (vi) a short-term interest rate, i.e. Treasury-Bill 3-months secondary market rate.[13] All variables are obtained from the FRED database of the Federal Reserve Bank of St. Louis, and, with the exception of the short-term interest rate, are in logarithms and are seasonally adjusted.[14] The real variables are deflated by their own price index.[15] Since each variables in y has a unit root[16], the inclusion of a specific linear

[13] The VAR specification follows other papers that study the market of durable goods (among others, Erceg and Levin (2006) and Monacelli (2009)).

[14] See Appendix 1.1 for details.

[15] Results are quantitatively similar if we deflate all nominal quantities in y by the CPI, or if we include the GDP deflator instead of the CPI in y and deflate all the nominal variables by the GDP deflator.

[16] Based on results of three tests: Augmented Dickey-Fuller, Phillips-Perron, and KPSS tests.

time trend[17] in z is required to achieve a stable VAR.

As mentioned in Section 1.2, there is an asymmetric information problem between agents and the econometrician that brings to the estimated VAR the same invertibility problem as in Leeper and Walker (2011) and Leeper et al. (2008). The VAR estimated by the econometrician cannot extract the news components contained in agents' information set, nor can econometrician retrieve the correct structural shocks by using current and past observable data. Our approach deals with this issue by bringing directly into the VAR vector x, a $T \times 1$ vector, which contains, in turn, one of the news shocks recovered via the Kalman filtering method described in Section 1.2, namely ϵ^1, ϵ^2, ϵ^3 and ϵ^4. Only news shocks from the baseline specification are used.[18] Given that news shocks are stationary, we impose that the constant and the coefficient on the time trend corresponding to the news shocks in H are both zero.[19]

The model described in Section 1.2 imposes restrictions on the VAR specification in (1.12). Because news shocks are vectors of innovations by definition, we need to impose block exogeneity restrictions by assuming that news shocks are, first, not affected by their own lags and, second, are not affected by the variables contained in y, even though the latter are affected by news shocks. Formally, the matrices G_i, for $i \in \{1, ..., p\}$, have the following form:

$$G_i = \begin{pmatrix} 0_{1\times 1} & 0_{1\times n_y} \\ G_{i,21} & G_{i,22} \end{pmatrix}. \tag{1.13}$$

The VAR process is estimated in levels by maximum likelihood with quarterly data over the sample going from 1981Q3 to 2010Q4. In all specifications, the Bayesian-Schwartz information criterion gives an optimal choice of one lag.[20]

[17] The test developed by Andrews (1993) with approximated p-values computed using the techniques developed in Hansen (1997) is conducted, and the null hypothesis of no structural break cannot be rejected for each variables in y. Therefore, no structural break in the linear time trend is allowed.

[18] Results were quantitatively similar using the news shocks from the alternative specification.

[19] For all news shocks, a likelihood ratio test fails to reject these restrictions.

[20] The Hannan-Quinn and Akaike information criterions give an optimal choice of one, two, or three lags depending on the specifications. Due to the small sample at hand, estimating the model with three lags was often problematic. The estimations with two lags yield quantitatively similar results, both in shape and magnitude.

In addition to the restrictions on G_i, given that the anticipated monetary shocks contained in vector x are already identified, we need to ensure that they do not react contemporaneously to other disturbances in the VAR. For this reason, we use, as identification scheme, the Cholesky decomposition (Sims, 1980; Christiano et al., 1999), and give news shocks the first rank in the VAR in (1.12).

1.3.2 Results

Figure 1.1 reports the estimated dynamic responses over a forecast horizon of 20 quarters of real GDP, real durable goods consumption, the real price of durable goods, the price index and the short-term interest rate to unanticipated (surprise) monetary policy tightening.[21] Figures 1.2 to 1.5 report the estimated dynamic responses of the same indicators to anticipated (news) monetary policy tightening, under our four specifications. These impulse response functions show how each of the five variables of interest responds on average over the sample to a one-standard-deviation unanticipated or anticipated monetary policy shock. The dashed curves represent the 90 percent confidence interval around the estimated response functions, computed using the bootstrap-after-bootstrap bias-correction methodology developed by Kilian (1998).[22]

[21] We not do report estimated impulse responses to unanticipated (surprise) monetary policy tightening for all specifications, but only to the one with $x_t = \epsilon_t^1$, since all specifications yield quantitatively similar results in terms of shape, magnitude and significance.

[22] We first compute 1000 bootstrap replications to approximate the small-sample bias. We then compute 2000 bootstrap replications using the bias correction found in the first step. As nonparametric bootstrap, we used the stationary bootstrap (Politis and Romano, 1994) with automatically selected average block length (Politis and White, 2004; Politis et al., 2009).

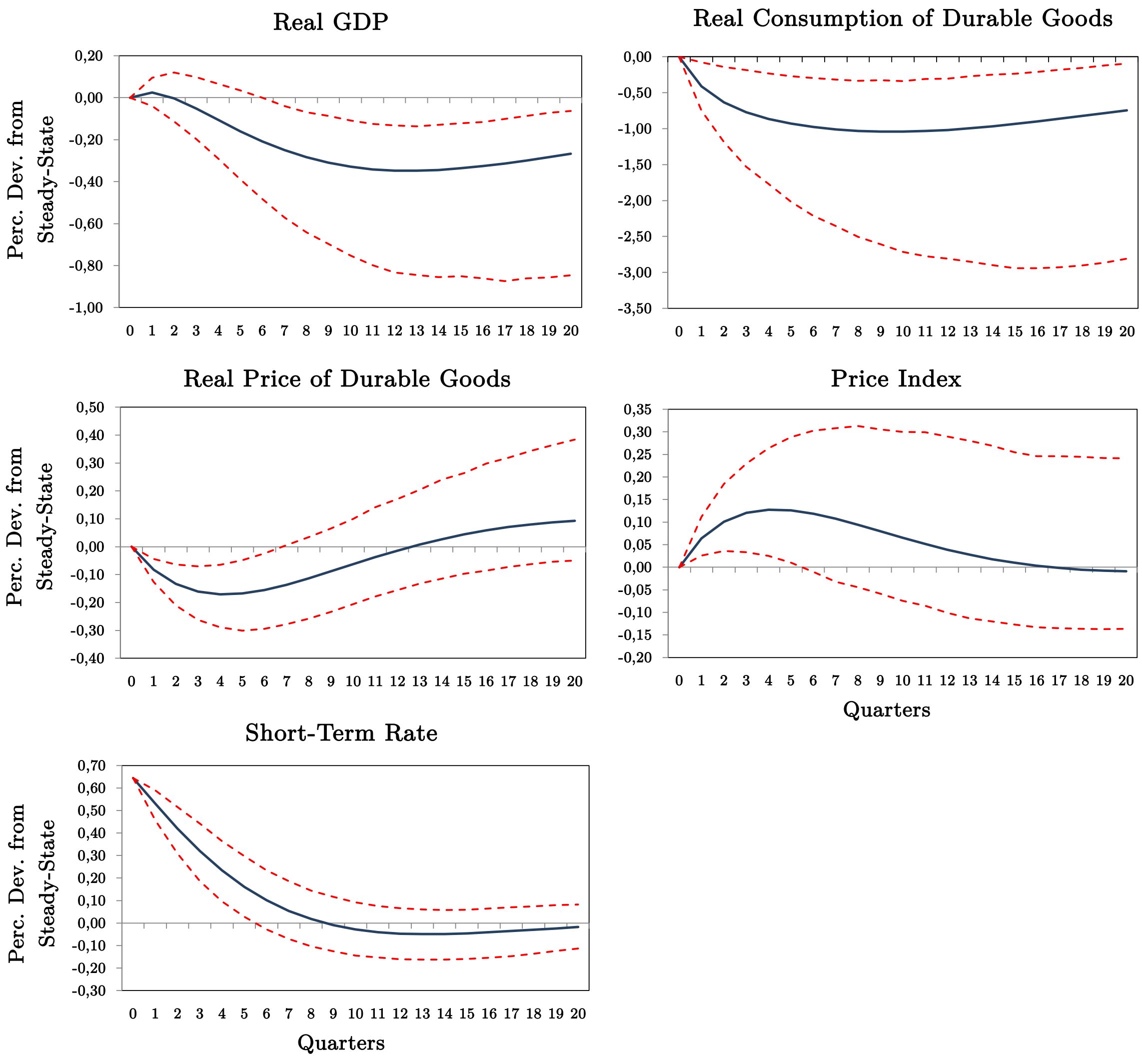


Figure 1.1: Estimated Impulse Responses to an Unanticipated Monetary Policy Tightening - Specification with Real GDP

From Figure 1.1, we see that both real GDP and consumption of durable goods react negatively to an unanticipated policy tightening. These results are consistent with previous findings (Erceg and Levin, 2006; Monacelli, 2009). The estimates imply that a one-standard-deviation shock causes a decrease in spending on durable goods on impact and this effect peaks in quarter 10 with a 1 percent deviation from the trend. In contrast, the peak of the real GDP reaction happens later (quarter 14) and its magnitude is three time smaller than for spending on durable goods. The results also present the usual price puzzle obtained using the Cholesky decomposition, i.e., an unanticipated monetary policy tightening induces a rise in the level of the price index compared to its time trend. However, the real price of durable goods decreases significantly and reaches a low at quarter 4, with a deviation of 0.1 percentage point from its trend. These results are robust to the specification of alternative orderings, the addition of one additional lag, and to the introduction of alternative variables.

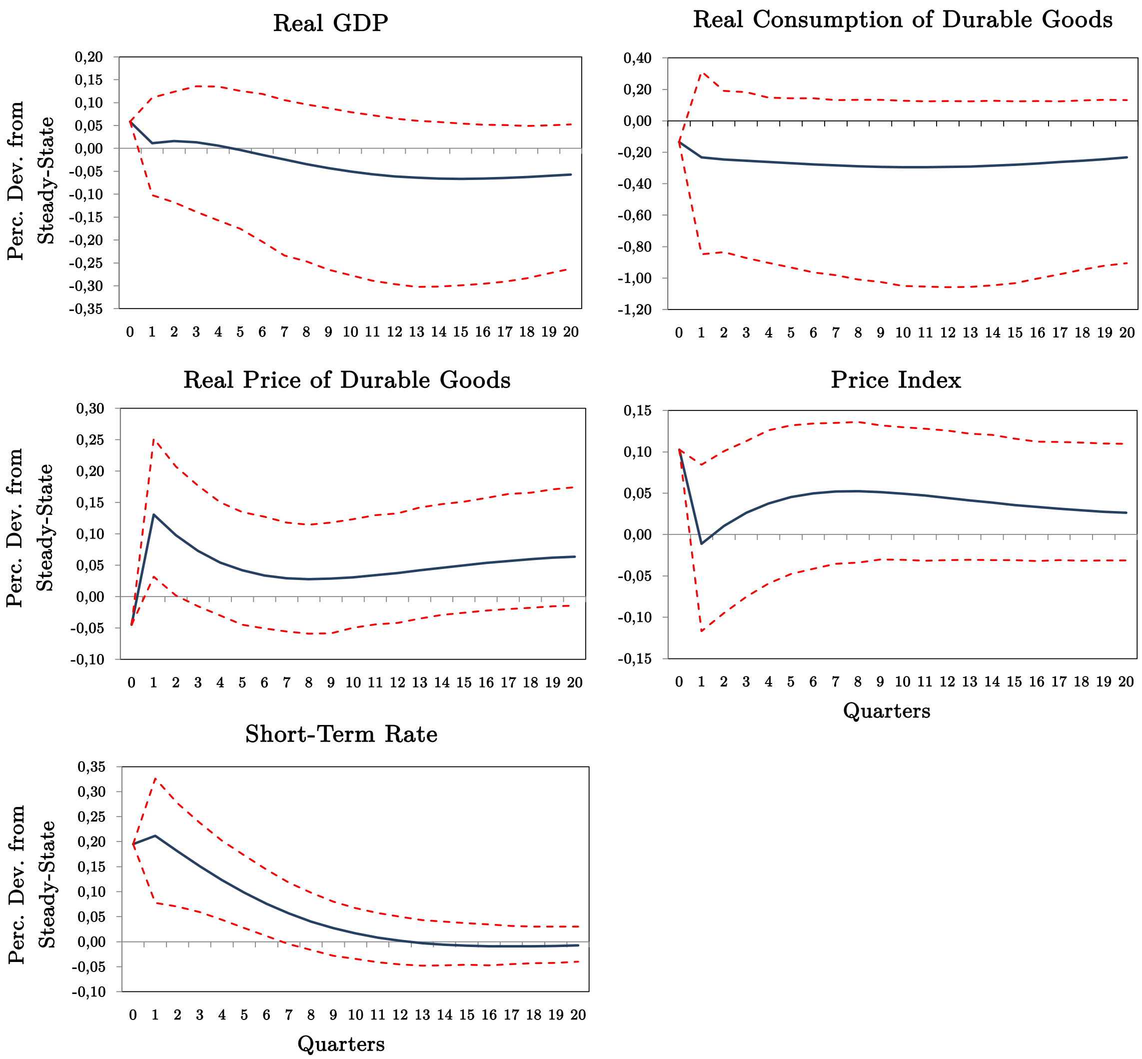


Figure 1.2: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening One Quarter Ahead - Specification with Real GDP

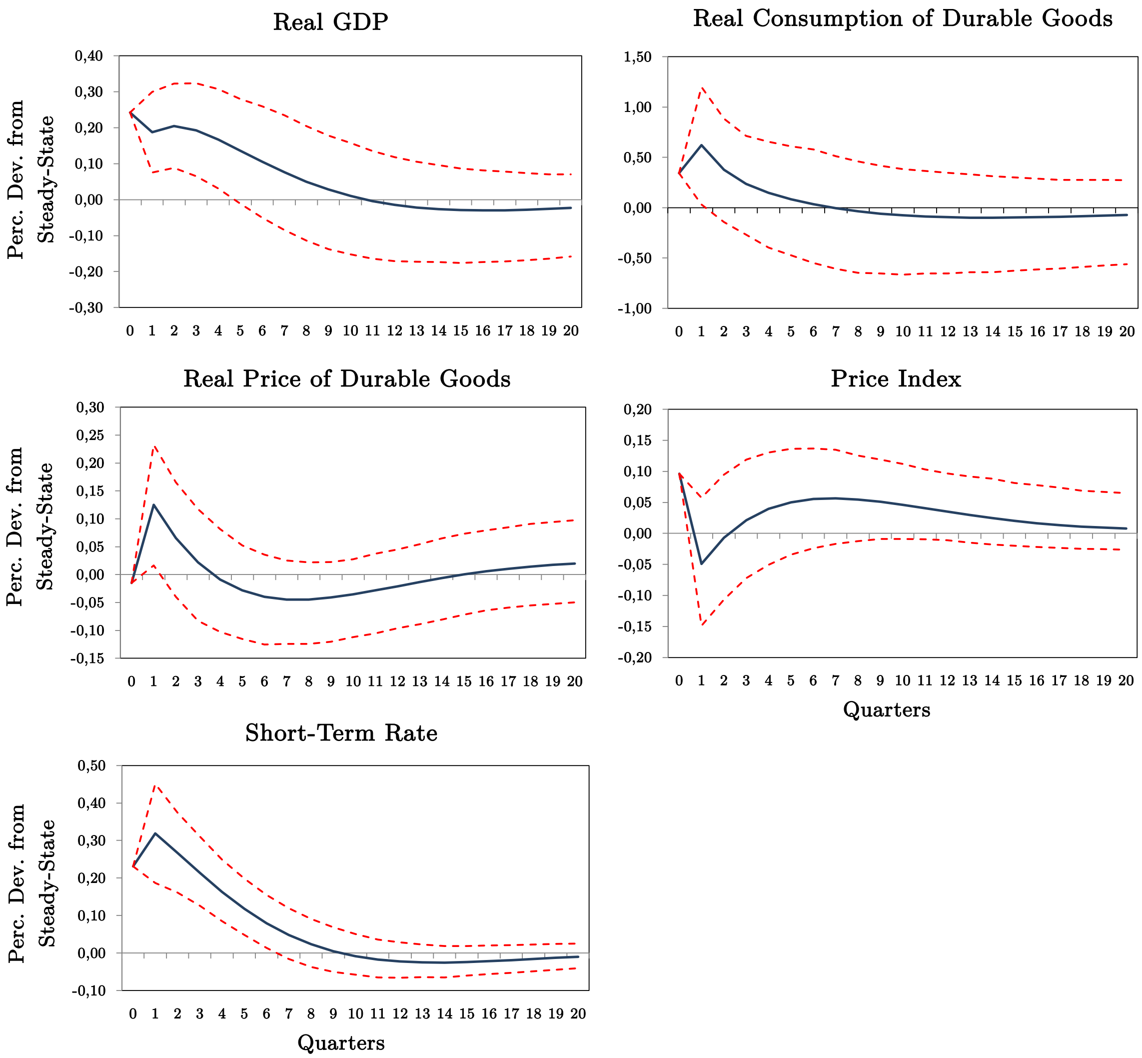


Figure 1.3: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Two Quarters Ahead - Specification with Real GDP

The responses of real durable goods consumption and the real price of durable goods to anticipated monetary policy tightening, shown in Figures 1.2 to 1.5, are of primary interest for this chapter. Three main results can be highlighted. First, for any expected monetary policy tightening, real GDP and real spending on durable goods exhibit strong co-movements and the peak reaction of real durable goods consumption is always two to three times larger than the one of real GDP. That being said, as shown in Figure 1.2, the initial reaction of real GDP and real consumption of durable goods to one-quarter-ahead news shocks are negatively correlated. The two response functions move together afterwards.

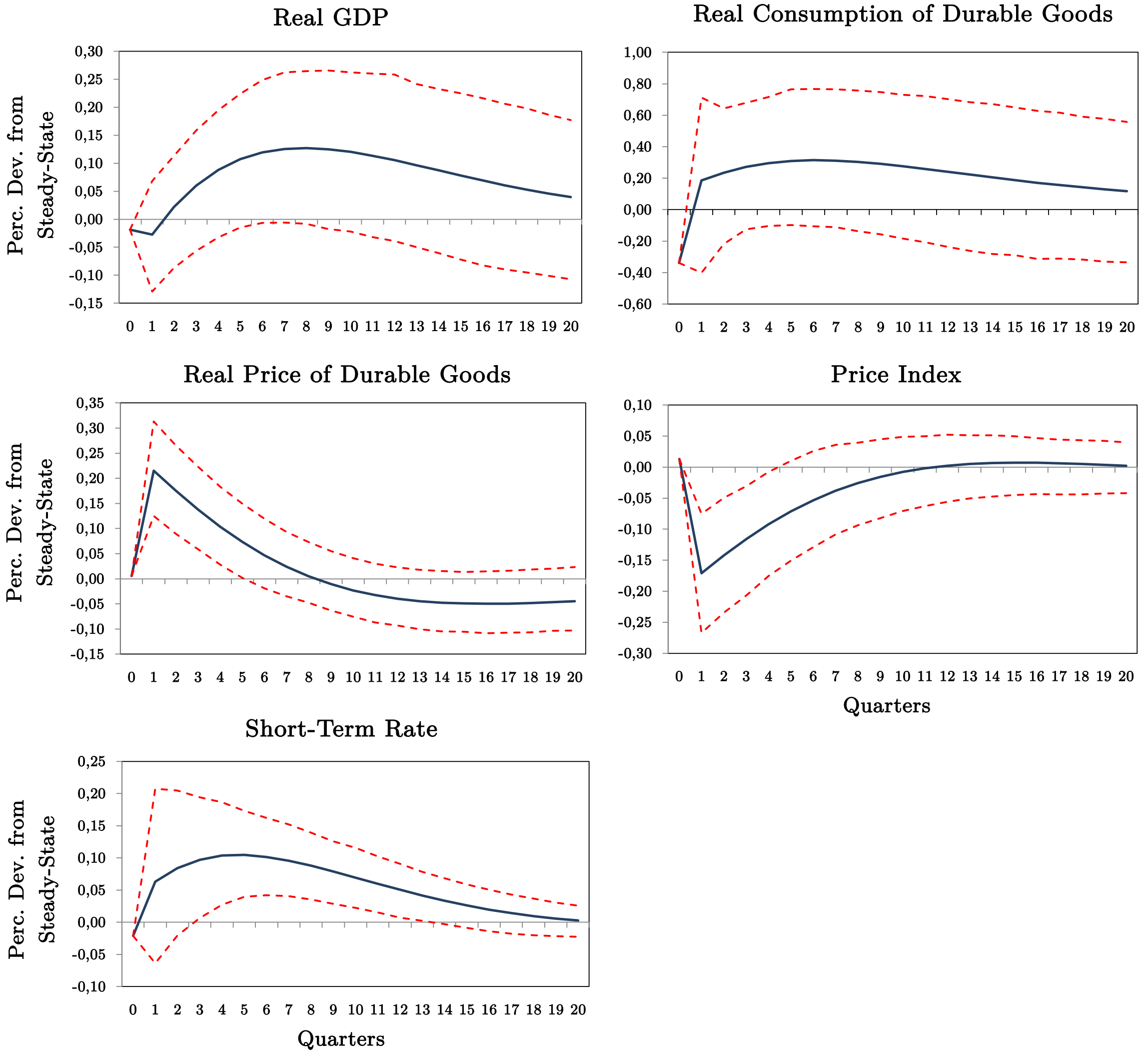


Figure 1.4: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Three Quarters Ahead - Specification with Real GDP

Second, the time horizon of the news shocks seems critical to the reaction of real GDP and real durable goods consumption. While an expected monetary policy tightening one quarter ahead induces a decline in durable goods consumption on impact of 0.2 percentage point from its trend, the opposite occurs for news shocks two to four quarters ahead. The peak reactions to those three anticipated shocks range from 0.5 to 0.7 percentage point.[23] Although these reactions are smaller then the one following a surprise shock, they nonetheless have a powerful effect on durable goods consumption and real GDP given that anticipated shocks are only expectations, not realizations.

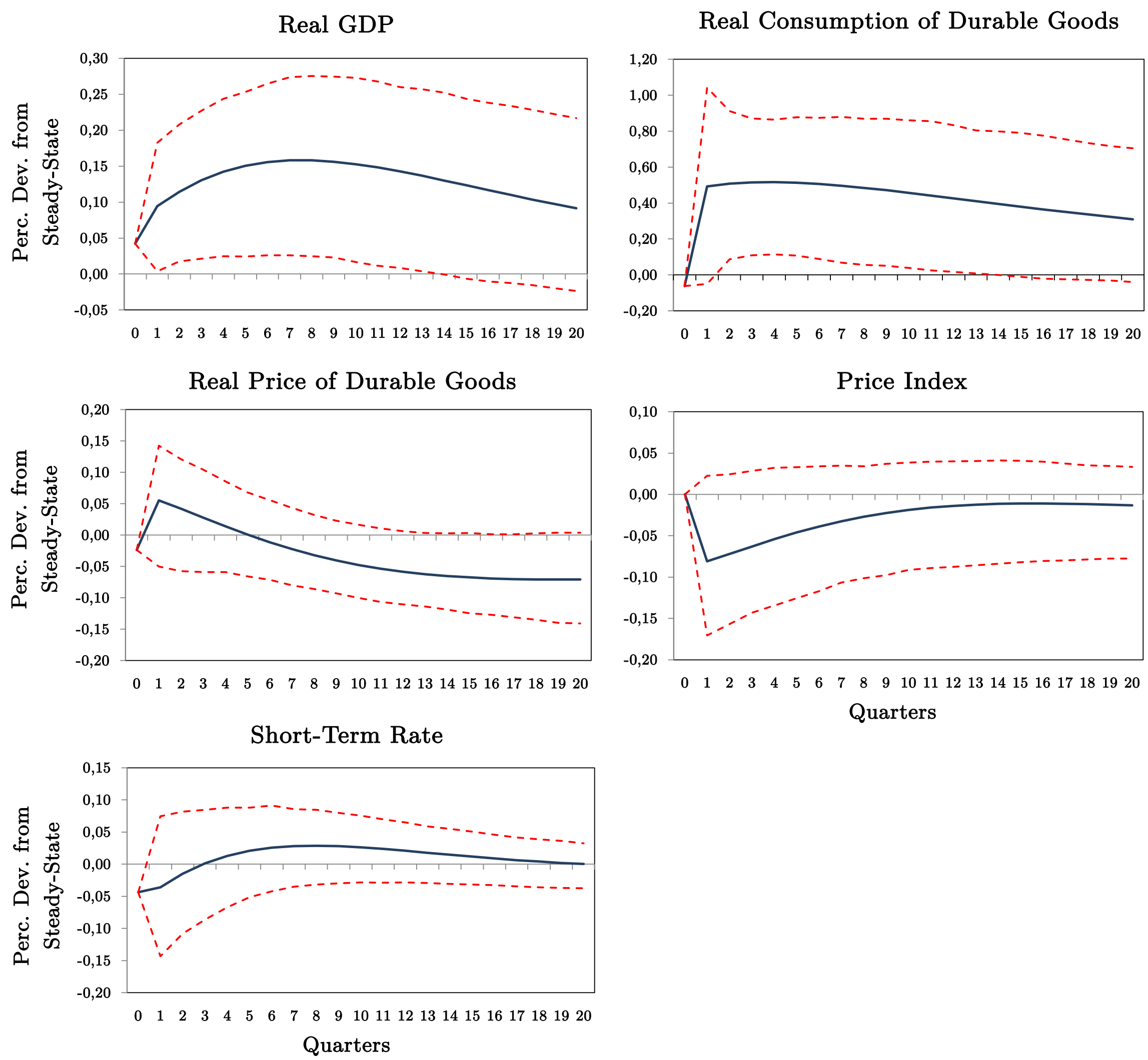


Figure 1.5: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Four Quarters Ahead - Specification with Real GDP

Third, with the exception of the one-quarter-ahead news shocks, we always observe a positive co-movement between real durable goods consumption and real price of durable goods following an anticipated monetary policy tightening. The effect on the former is,

[23] For the news shocks three quarters ahead, we observe a small decrease on impact, but the estimated dynamic response quickly goes back to positive values.

however, two to six times larger.

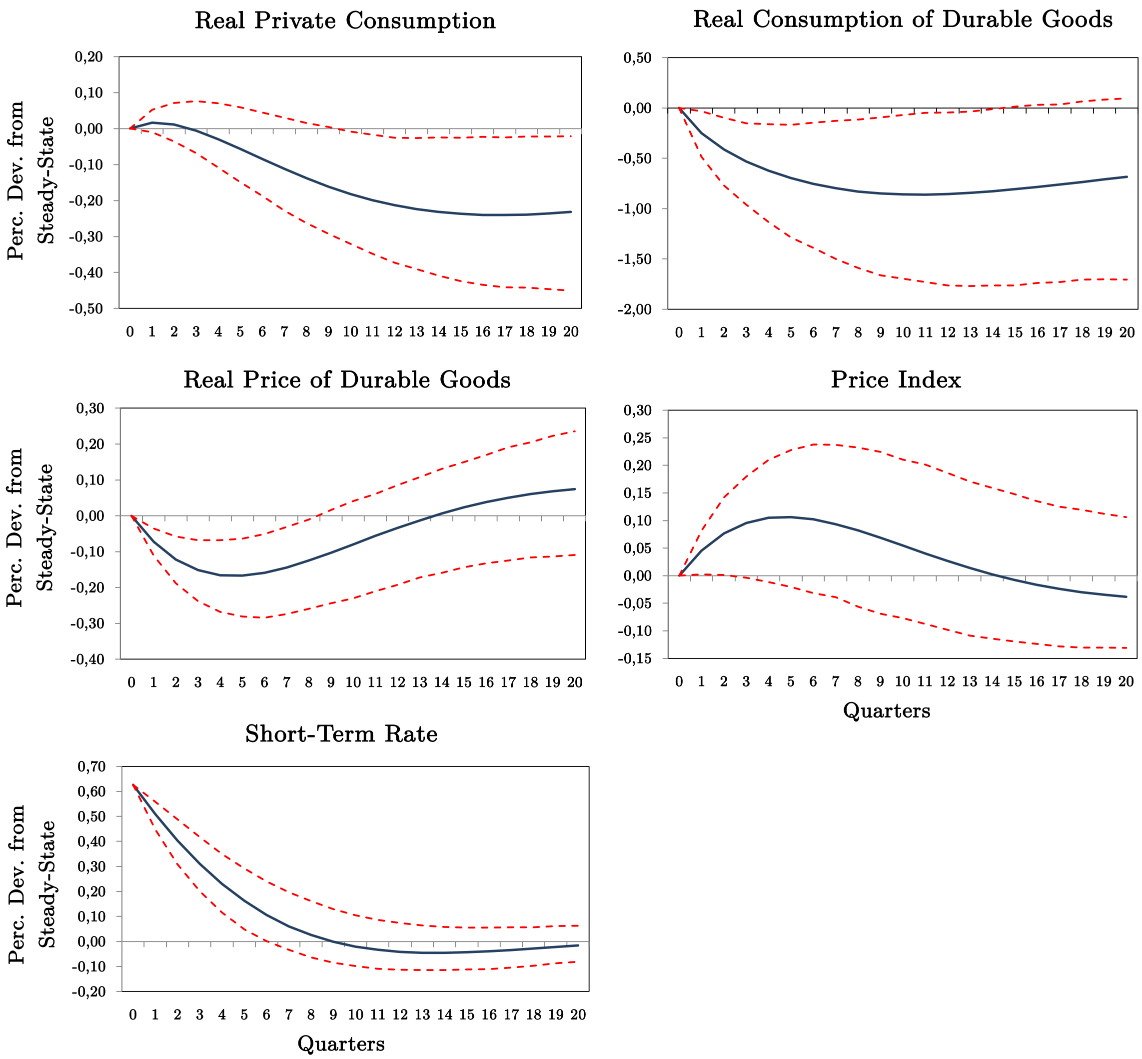


Figure 1.6: Estimated Impulse Responses to an Unanticipated Monetary Policy Tightening - Specification with Real Private Consumption

As a second specification, we substitute real GDP for real private consumption excluding durable goods consumption, to explore the co-movement between spending on non-durable goods and services and durable goods consumption. The results are broadly consistent with the dynamic responses from the specification with real GDP. From Figure 1.6, we see that both the real private consumption, durable goods consumption and real price of durable goods react negatively to an unanticipated policy tightening.

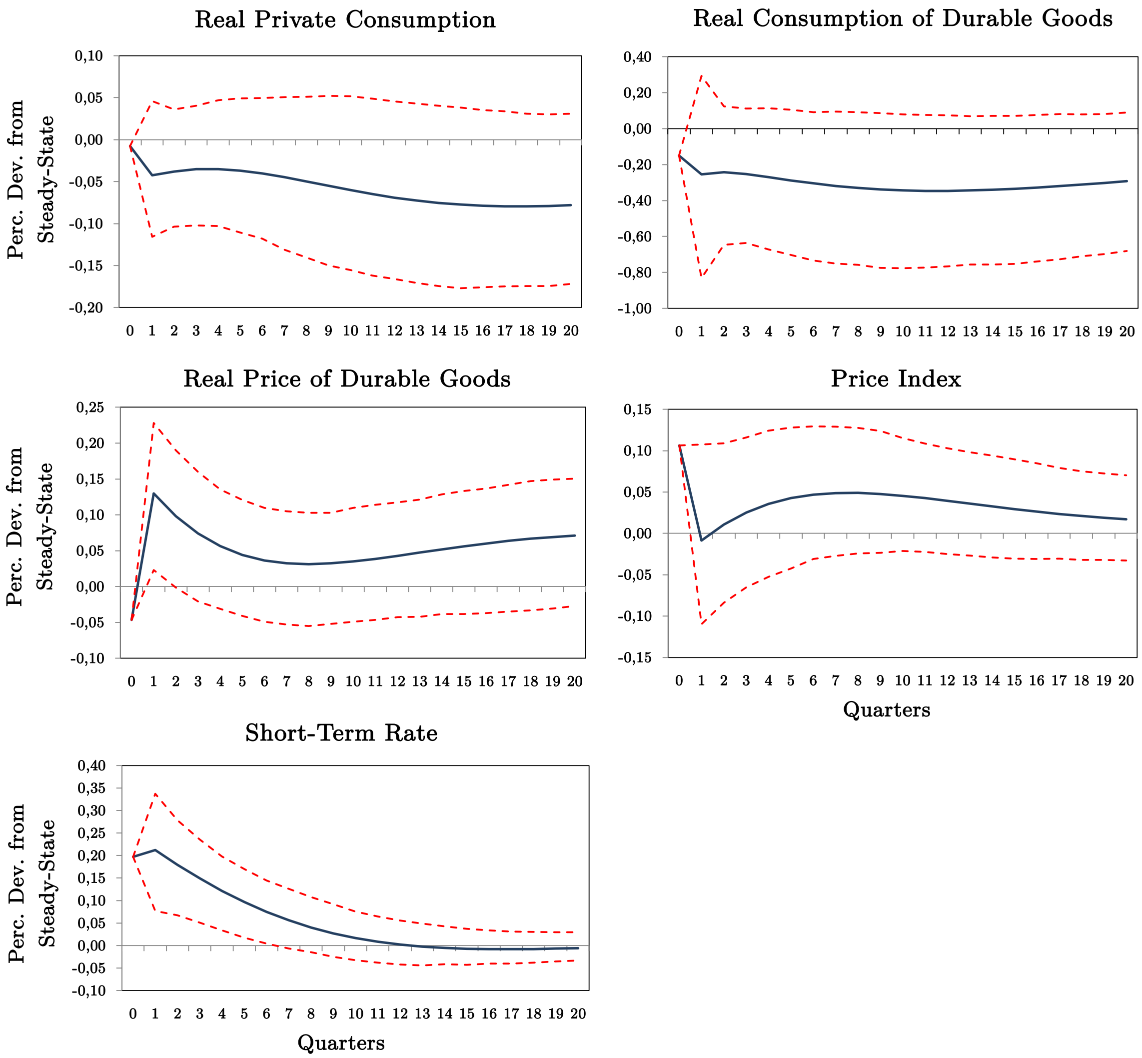


Figure 1.7: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening One Quarter Ahead - Specification with Real Private Consumption

The responses of the durable goods consumption and the real price of durable goods following an anticipated monetary policy tightening are shown in Figures 1.7 to 1.10. First, in contrast with the specification with real GDP, the initial reactions of non-durable and durable goods consumption are often negatively correlated. The two responses function move together afterwards.

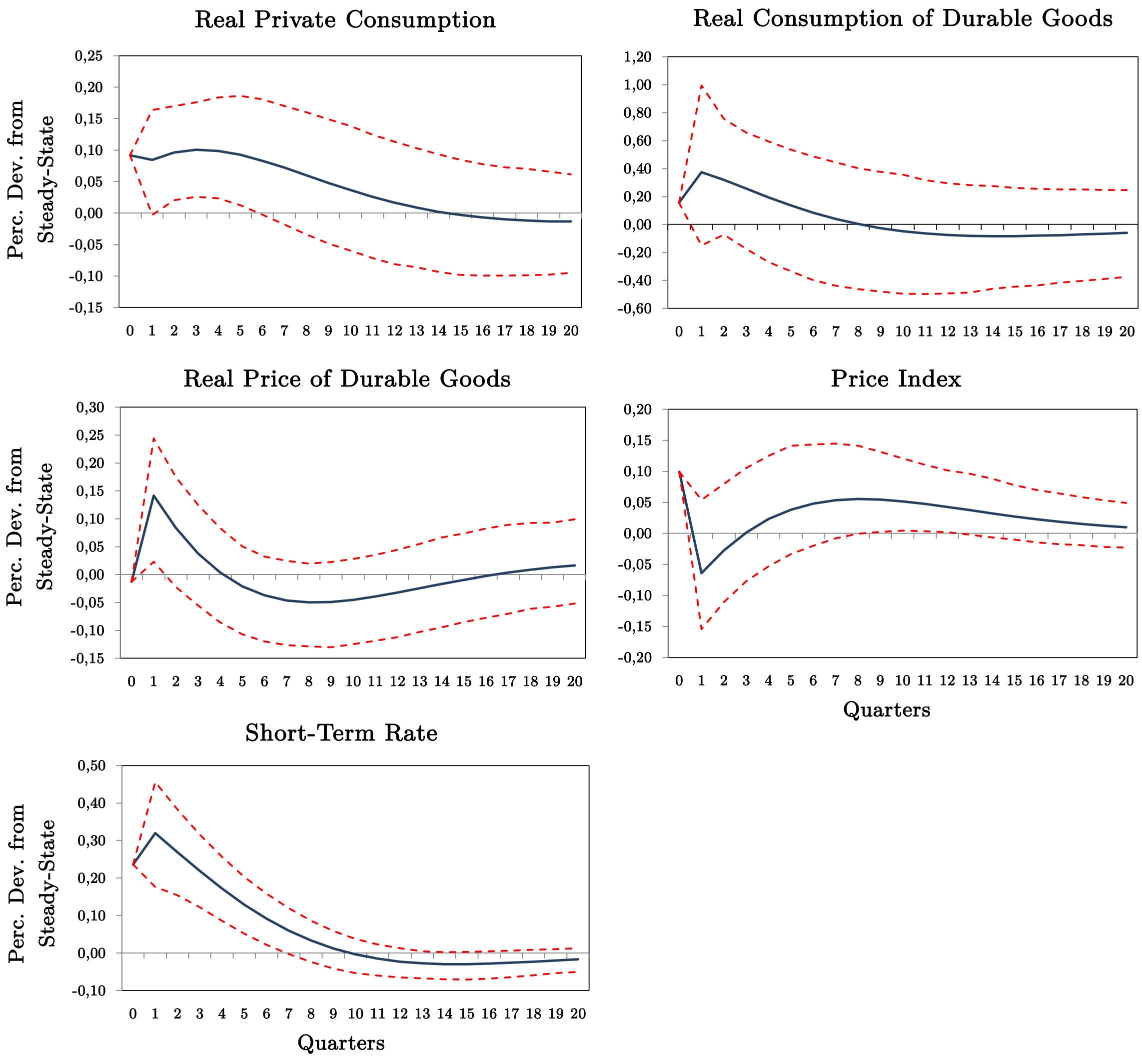


Figure 1.8: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Two Quarters Ahead - Specification with Real Private Consumption

Second, as in the first specification, the time horizon of the news shocks seems critical to the reaction of real private consumption and real durable goods consumption. While an expected monetary policy tightening one quarter ahead induces a decrease in durable goods consumption on impact, with a decrease of 0.2 percentage point from its trend, the opposite occurs for news shocks two to four quarters ahead. The peak reactions to those three anticipated shocks range from 0.5 to 0.7 percentage point.

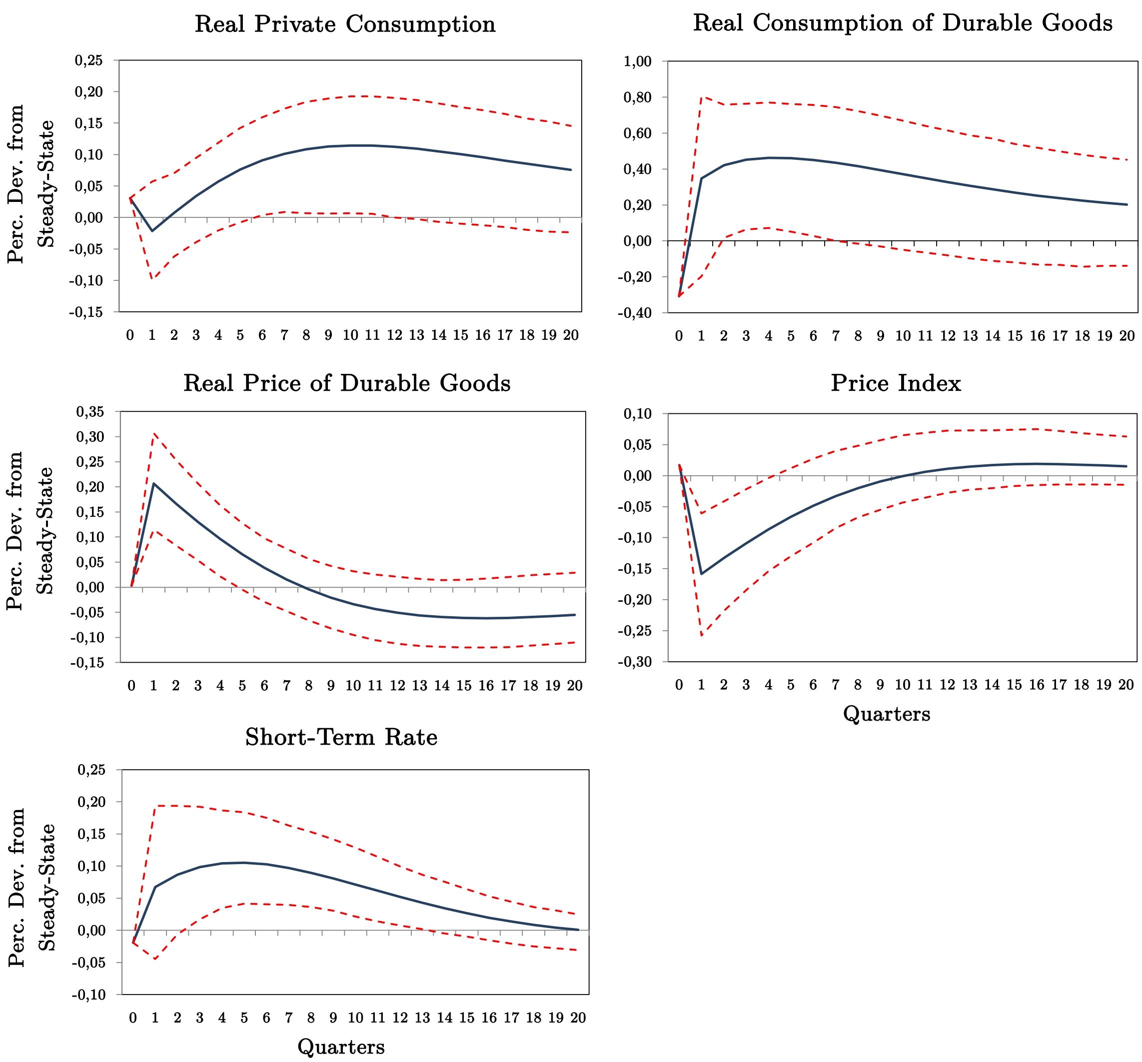


Figure 1.9: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Three Quarters Ahead - Specification with Real Private Consumption

Third, as in the previous specification, with the exception of the one-quarter-ahead news shocks, we always observe a positive co-movement between real spending on durable goods and real price of durable goods, although the effect on the former is two to six times larger.

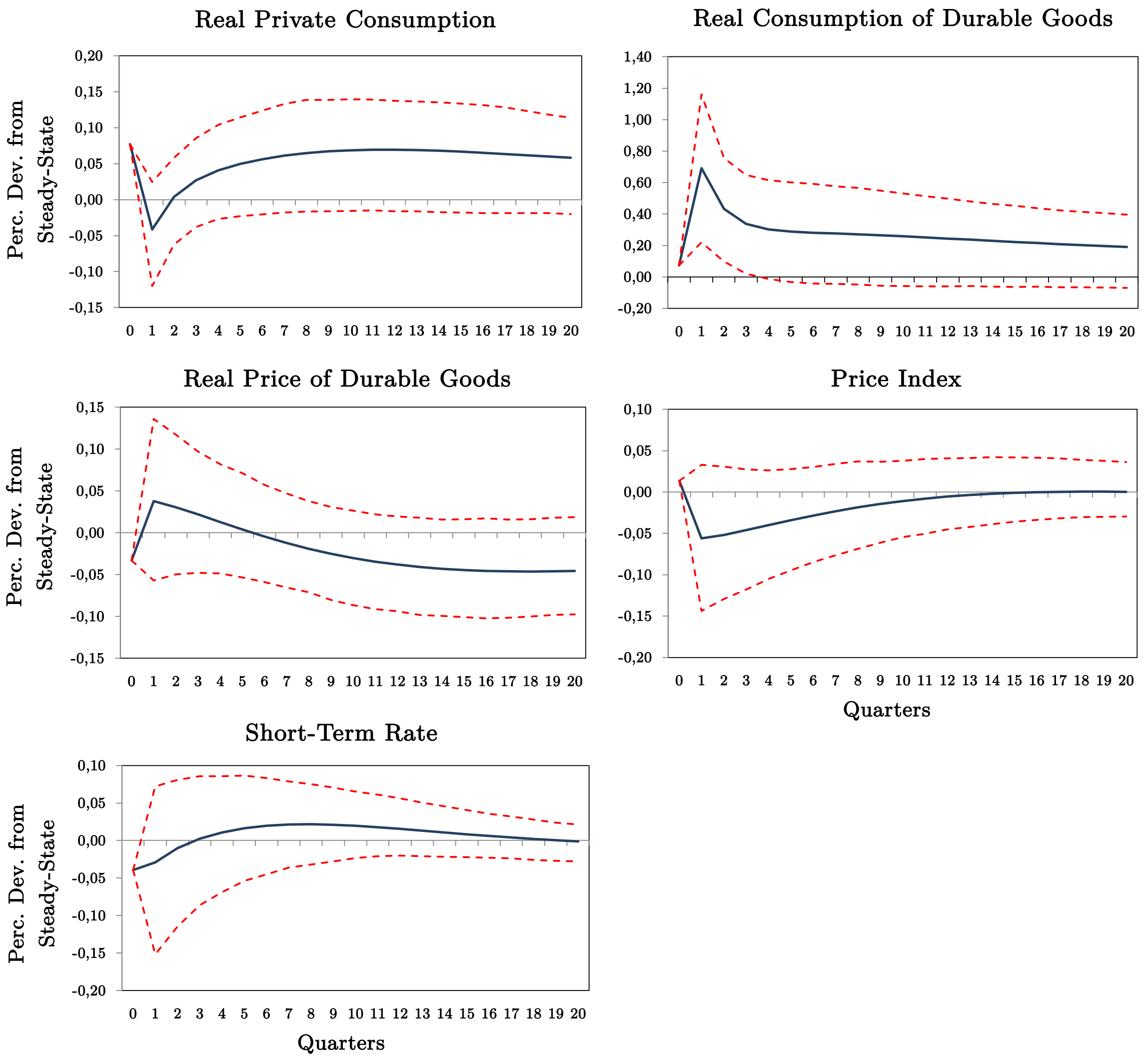


Figure 1.10: Estimated Impulse Responses to an Anticipated Monetary Policy Tightening Four Quarters Ahead - Specification with Real Private Consumption

1.4 A Model of Durable Consumption with News Shocks

In this section, we consider an economy populated by two types of households, designated as borrowers and lenders, in the spirit of Monacelli (2009). Credit flows are generated by assuming *ex-ante* heterogeneity in agents' subjective discount factors. Impatient consumers (borrowers) differ from patient consumers (lenders) in that they discount the future at a faster rate. Hence, in equilibrium, patient agents are net lenders while impatient agents are net borrowers. To prevent borrowing from growing without limit, we assume that borrowers face credit constraints tied to the expected future value of their collateral.

There are two sectors of production in the economy: durable and non-durable consumption goods. Each sector has final good producers that evolve in perfect competition market, and continuum of sector-specific intermediate good producers. Each intermediate good producer uses labor to produce a differentiated good, and *de facto* acts as a monopolistic competitor. Prices are set in a staggered fashion *à la* Calvo (1983). Households supply labor and buy final goods, deriving their utility from consumption of non-durable goods and the service flow produced by the stock of durable goods. Finally, a central bank conducts monetary policy according to a Taylor-type rule.

1.4.1 Economic Environment

1.4.1.1 Households

Households k, with $k \in \{l, b\}$, derive strictly increasing utility from the consumption of non-durable goods $c_{k,t}$ and from services provided by the durable goods stock $d_{k,t}$. Households supply labour and derive a strictly decreasing utility from hours worked in the non-durable goods production sector, $l^c_{k,t}$, and hours worked in the durable goods production sector, $l^d_{k,t}$. They maximize their expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_k^t U\left(x_{k,t}, l_{k,t}\right), \tag{1.14}$$

where E_0 is the mathematical expectation given at time 0 information set, $\beta_k \in (0,1)$ is the subjective discount factor, and the functional form of U is

$$U\left(\bullet\right) = \log\left(x_{k,t}\right) - \frac{\nu}{1+\sigma} l_{k,t}^{1+\sigma}. \tag{1.15}$$

The final good $x_{k,t}$ is defined as a CES composite of non-durable goods $c_{k,t}$ and durable goods stock $d_{k,t}$

$$x_{k,t} = \left[(1-\alpha)^{\frac{1}{\eta}} c_{k,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{k,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{1.16}$$

and $l_{k,t}$ is the sum of hours worked in both sectors, $l_{k,t} = l^c_{k,t} + l^d_{k,t}$, with $0 \leq l_{k,t} \leq 1$. The two types of households k are distinguished by their time-discount rates, β_l and β_b. α is the share of durable goods in the composite consumption index. η is the strictly positive elasticity of substitution between non-durable and durable goods. When $\eta \to 0$, non-durable and durable goods are perfect complements, whereas the two goods are perfect substitutes when $\eta \to \infty$. Finally, σ is the inverse of the Frish elasticity of substitution and ν represents the loss in utility from providing hours of work.

Lenders Lenders ($k = l$) have a higher propensity to save (i.e. $\beta_l > \beta_b$). In equilibrium, they supply loans to borrowers (impatient households, $k = b$) and accumulate stock of durable goods. Since the lenders are the owners of the firms in both sector, they receive dividends, f^c_t and f^d_t, from the non-durable goods and durable goods production sectors, respectively. They maximize their expected lifetime utility (1.14) subject to their budget constraint in real terms (in units of non-durable goods)

$$c_{l,t} + q_t i_{l,t} + b_{l,t} = w^c_{l,t} l^c_{l,t} + w^d_{l,t} l^d_{l,t} + \frac{R_{t-1} b_{l,t-1}}{\pi^c_t} + f^c_t + f^d_t, \tag{1.17}$$

and the law of motion for durable goods

$$i_{l,t} = d_{l,t} - (1 - \delta)\, d_{l,t-1}, \tag{1.18}$$

where $i_{l,t}$ is the investment in durable goods stock, $q_t = P^d_t \big/ P^c_t$ is the relative price of durable goods, $\pi^c_t = P^c_t \big/ P^c_{t-1}$ is the non-durable goods gross inflation rate, $w^c_{l,t}$ is the wage received for the hours worked in the non-durable goods production sector, and $w^d_{l,t}$ is the wage received for the hours worked in the durable goods production sector. There is also the gross nominal interest rate R_t on bonds $b_{l,t}$[24], and the durable goods depreciation rate, δ.

Substituting (1.18) into (1.17), the first-order necessary conditions for $c_{l,t}$, $d_{l,t}$, $l^c_{l,t}$, $l^d_{l,t}$ and

[24]We use the convention that $b < 0$ is debt and $b > 0$ is savings.

$b_{l,t}$ are, respectively,

$$\lambda^c_{l,t} = \frac{(1-\alpha)^{\frac{1}{\eta}} c_{l,t}^{\frac{-1}{\eta}}}{(1-\alpha)^{\frac{1}{\eta}} c_{l,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{l,t}^{\frac{\eta-1}{\eta}}}, \tag{1.19}$$

$$\lambda^c_{l,t} q_t - \beta_l (1-\delta) E_t \left[\lambda^c_{l,t+1} q_{t+1}\right] = \frac{\alpha^{\frac{1}{\eta}} d_{l,t}^{\frac{-1}{\eta}}}{(1-\alpha)^{\frac{1}{\eta}} c_{l,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{l,t}^{\frac{\eta-1}{\eta}}}, \tag{1.20}$$

$$\nu l_{l,t}^{\sigma_n} = \lambda^c_{l,t} w^c_{l,t}, \tag{1.21}$$

$$\nu l_{l,t}^{\sigma_n} = \lambda^c_{l,t} w^d_{l,t}, \tag{1.22}$$

and

$$\lambda^c_{l,t} = \beta_l R_t E_t \left[\frac{\lambda^c_{l,t+1}}{\pi^c_{t+1}}\right], \tag{1.23}$$

where $\lambda^c_{l,t}$ is the Lagrange multiplier on budget constraint (1.17). Equation (1.19) describes the marginal utility of current consumption of non-durable goods. Equation (1.20) requires that the households equates the marginal utility of consumption of current non-durable goods to the marginal gain of durable goods services. The marginal gain of durable services includes two parts: (i) the direct utility gain of an additional unit of durable goods, and (ii) the expected utility stemming from the consumption of the resale value of durable goods purchased in previous periods. Equations (1.21) and (1.22) links the real wages (in units of non-durable goods) in both sectors to the households' marginal rate of substitution between non-durable goods consumption and leisure. In equilibrium, the real wages in non-durable goods and durable goods production sectors are equal. Equation (1.23) is the typical Euler condition, that equates the cost of sacrificing one unit of non-durable goods consumption to the benefit of investing in bond market.

Borrowers The impatient households, that is the borrowers b, maximize their expected lifetime utility (1.14) subject to a budget constraint

$$c_{b,t} + q_t i_{b,t} + b_{b,t} = w^c_{b,t} l^c_{b,t} + w^d_{b,t} l^d_{b,t} + \frac{R_{t-1} b_{b,t-1}}{\pi^c_t}, \tag{1.24}$$

and the law of motion for durable goods

$$i_{b,t} = d_{b,t} - (1-\delta)\, d_{b,t-1}, \tag{1.25}$$

where $w_{b,t}^{c}$ is the wage received for the hours worked in the non-durable goods production sector, and $w_{b,t}^{d}$ is the wage received for the hours worked in the durable goods production sector.

Private borrowing is subject to an endogenous limit. At any time t, the amount that the borrowers agree to repay in the following period is tied to the expected future value of their durable goods stock (after depreciation):

$$b_{b,t} \geq -\frac{\chi\,(1-\delta)\, d_{b,t}}{R_t} E_t\left[q_{t+1}\pi_{t+1}^{c}\right], \tag{1.26}$$

where χ is the fraction of the durable good value that can be used as a collateral (i.e. loan-to-value ratio) (Kiyotaki and Moore, 1997; Monacelli, 2009).

Substituting (1.25) into (1.24), the first-order necessary conditions for $c_{b,t}$, $d_{b,t}$, $l_{b,t}^{c}$, $l_{b,t}^{d}$ and $b_{b,t}$ are, respectively,

$$\lambda_{b,t}^{c} = \frac{(1-\alpha)^{\frac{1}{\eta}} c_{b,t}^{\frac{-1}{\eta}}}{(1-\alpha)^{\frac{1}{\eta}} c_{b,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{b,t}^{\frac{\eta-1}{\eta}}}, \tag{1.27}$$

$$\begin{aligned} \lambda_{b,t}^{c} q_t - \beta_b (1-\delta)\, E_t\left[\lambda_{b,t+1}^{c} q_{t+1}\right] = & \frac{\alpha^{\frac{1}{\eta}} d_{b,t}^{\frac{-1}{\eta}}}{(1-\alpha)^{\frac{1}{\eta}} c_{b,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{b,t}^{\frac{\eta-1}{\eta}}} + \\ & \frac{\lambda_{b,t}^{c}\lambda_{b,t}^{b}\chi\,(1-\delta)}{R_t} E_t\left[q_{t+1}\pi_{t+1}^{c}\right], \end{aligned} \tag{1.28}$$

$$\nu l_{b,t}^{\sigma_n} = \lambda_{b,t}^{c} w_{b,t}^{c}, \tag{1.29}$$

$$\nu l_{b,t}^{\sigma_n} = \lambda_{b,t}^{c} w_{b,t}^{d}, \tag{1.30}$$

and

$$\lambda_{b,t}^{c}\left(1-\lambda_{b,t}^{b}\right) = \beta_b R_t E_t\left[\frac{\lambda_{b,t+1}^{c}}{\pi_{t+1}^{c}}\right], \tag{1.31}$$

where $\lambda_{b,t}^{c}$ is the Lagrange multiplier on budget constraint (1.24), and $\lambda_{b,t}^{c}\lambda_{b,t}^{b}$ is the Lagrange multiplier on borrowing constraint (1.26). Equations (1.27), (1.29) and (1.30) have the same interpretation as for the lenders. Equation (1.28) depend on the same two components of the lenders' equation (1.20), but also on the marginal utility of relaxing the borrowing constraint. Equation (1.31) is modified version of the typical Euler equation. With a non-binding constraint, i.e. $\lambda_{b,t}^{b} = 0$ for all t, it reduces to a standard Euler condition. With a binding constraint, the marginal value of borrowing is tied to a payoff that captures the deviation from the Euler condition. If $\lambda_{b,t}^{b} \geq 0$, we have

$$\lambda_{b,t}^{c} > \beta_b R_t E_t \left[\frac{\lambda_{b,t+1}^{c}}{\pi_{t+1}^{c}} \right]. \tag{1.32}$$

In other words, the marginal utility of consumption exceeds the marginal gain of shifting one unit of consumption intertemporally (Monacelli, 2009).

1.4.1.2 Final good producers

We assume that the packaging of durable and non-durable goods is structured in the same way. In each period t, perfectly competitive final goods producers in each sector $j \in \{c, d\}$ purchase differentiated intermediate goods $m \in [0,1]$, to assemble final goods Y_t^j via the Dixit-Stiglitz aggregator

$$Y_t^j = \left[\int_0^1 \left(Y_{m,t}^j \right)^{\frac{\theta^j - 1}{\theta^j}} dm \right]^{\frac{\theta^j}{\theta^j - 1}}, \tag{1.33}$$

where the parameter $\theta^j > 1$ denotes the intratemporal elasticity of substitution across different varieties of differentiated goods and $Y_{m,t}^j$ is the demand for goods of variety m in sector j.

Final goods producers take as given the prices of intermediate goods and the aggregate price index when maximizing profits. For any given level of composite final goods produced in sector j, they must solve the expenditure-minimizing problem

$$\min_{\left\{Y_{m,t}^j\right\}} \int_0^1 P_{m,t}^j Y_{m,t}^j dm,$$

subject to aggregation constraint (1.33), where $P^j_{m,t}$ denotes the price of the intermediate good m of sector j at time t. The demand for goods of variety m is then given by

$$Y^j_{m,t} = \left(\frac{P^j_{m,t}}{P^j_t}\right)^{-\theta^j} Y^j_t, \tag{1.34}$$

where P^j_t is a sector specific nominal price index defined as

$$P^j_t = \left[\int_0^1 \left(P^j_{m,t}\right)^{1-\theta_j} dm\right]^{\frac{1}{1-\theta_j}}. \tag{1.35}$$

1.4.1.3 Intermediate good producers

We assume that the production of durable and non-durable goods has the same production technology, with sector-specific total factor productivity. Since each type of intermediate goods is produced by a single firm in a monopolistic competitive environment, each sector j is populated by a continuum of firms indexed by $m \in [0,1]$. The constant return to scale production function for firm m in sector j is

$$Y^j_{m,t} = z^j_t \left(l^j_{l,m,t}\right)^{\omega} \left(l^j_{b,m,t}\right)^{1-\omega}, \tag{1.36}$$

where $Y^j_{m,t}$ is the total production by firm m, $l^j_{l,m,t}$ is the number of hours of work demanded by firm m from lenders, $l^j_{b,m,t}$ is the number of hours of work demanded by firm m from borrowers, z^j_t is the sector-wide total factor productivity, and ω is the lenders' share of total labour income. The nominal profits (i.e. dividends) of the firm are denoted by

$$F^j_{m,t} = P^j_{m,t} Y^j_{m,t} - W^j_{l,t} l^j_{l,m,t} - W^j_{b,t} l^j_{b,m,t},$$

where $W^j_{l,t}$ and $W^j_{b,t}$ are the nominal counterparts of the real wages contained in budget constraints (1.17) and (1.24). We assume that the firm must satisfy the demand for good

m at posted price

$$Y_{m,t}^j \geqslant \left(\frac{P_{m,t}^j}{P_t^j} \right)^{-\theta_j} Y_t^j. \tag{1.37}$$

The firm's objective is a static problem of profit maximization

$$\max_{\left\{ l_{l,m,t}^j, l_{b,m,t}^j \right\}} F_{m,t}^j \tag{1.38}$$

subject to demand function (1.37). Real wages are then given by

$$w_{l,t}^j = mc_t^j z_t^j \omega \left(l_{l,m,t}^j \right)^{\omega-1} \left(l_{b,m,t}^j \right)^{1-\omega}, \tag{1.39}$$

and

$$w_{b,t}^j = mc_t^j z_t^j \left(1-\omega\right) \left(l_{l,m,t}^j \right)^{\omega} \left(l_{b,m,t}^j \right)^{-\omega}, \tag{1.40}$$

where mc_t^j is the firm's real marginal cost. From the optimality conditions, all firms m face the same prices of factors, and since they have access to the same technology, marginal cost is equal across all firms at every period t.

Firms are able to reoptimize their prices as in Calvo (1983). Specifically, each firm faces a Calvo price rigidity, with a non-zero probability ξ^j of being unable to adjust its nominal price in a given period. The reoptimization probability is independently and identically distributed across firms and over time. Firms maximize the expected present value of their real dividends by maximizing the Lagrangian

$$L_m^j = E_t \sum_{s=0}^{\infty} \left(\beta_l \xi^j\right)^s \frac{\lambda_{l,t+s}^c}{\lambda_{l,t}^c} \frac{P_t^c}{P_{t+s}^c} \left\{ \begin{array}{l} \left[\tilde{P}_t^j \left(\frac{\tilde{P}_t^j}{P_{t+s}^j} \right)^{-\theta^j} Y_{t+s}^j - W_{l,t+s}^j l_{l,m,t+s}^j - W_{b,t+s}^j l_{b,m,t+s}^j \right] \\ +MC_{t+s}^j \left[z_{t+s}^j \left(l_{l,m,t+s}^j \right)^{\omega} \left(l_{b,m,t+s}^j \right)^{1-\omega} - \left(\frac{\tilde{P}_t^j}{P_{t+s}^j} \right)^{-\theta^j} Y_{t+s}^j \right] \end{array} \right\}.$$

where $\beta_l^s \frac{\lambda_{l,t+s}^c}{\lambda_{l,t}^c} \frac{P_t^c}{P_{t+s}^c} MC_{t+s}^j$ is the Lagrange multiplier on demand function (1.37), and MC_{t+s}^j is the firm's nominal marginal cost. Since firms are assumed to act in the best interests of their owners (that is, the lenders), the Lagrange multiplier is the marginal rate of substitution for non-durable goods over time (i.e. equation (1.23)). In setting its price in period t, the firm takes into account the fact that it may have to wait some time until it is able to reoptimize its price. In particular, the probability of not reoptimizing between dates t and $t+s$ is $(\xi^j)^s$. Since all reoptimizing firms face the same problem, all will choose the same $\tilde{P}_t^j$ as the optimal price.

Non-Durable Good Sector To maximize the expected present value of their real dividends, producers of the non-durable goods sector must meet the following first-order necessary condition with respect to $\tilde{P}_t^c$:

$$E_t \sum_{s=0}^{\infty} (\beta_l \xi^c)^s \frac{\lambda_{l,t+s}^c}{\lambda_{l,t}^c} \left(\frac{\tilde{P}_t^c}{P_t^c}\right)^{-\theta^c} \prod_{k=1}^{s} \left(\frac{1}{\pi_{t+k}^c}\right)^{-\theta^c} Y_{t+s}^c \left[\frac{\theta^c - 1}{\theta^c} \left(\frac{\tilde{P}_t^c}{P_t^c}\right) \prod_{k=1}^{s} \left(\frac{1}{\pi_{t+k}^c}\right) - mc_{t+s}^c\right] = 0.$$

According to this expression, optimizing firms set nominal prices to equate average future expected marginal revenues to average future expected marginal costs.

The expression above does not have a direct recursive formulation, making the computation difficult. It will be useful to write the price-setting equation in recursive form. We then need to define intermediate variables $x_t^{c,1}$ and $x_t^{c,2}$. This yields

$$x_t^{c,1} = \frac{\theta^c - 1}{\theta^c} \tilde{p}_t^{1-\theta^c} Y_t^c + \beta_l \xi^c E_t \left[\frac{\lambda_{l,t+1}^c}{\lambda_{l,t}^c} \left(\frac{1}{\pi_{t+1}^c}\right)^{1-\theta^c} \left(\frac{\tilde{p}_t^c}{\tilde{p}_{t+1}^c}\right)^{1-\theta^c} x_{t+1}^{c,1}\right], \tag{1.41}$$

$$x_t^{c,2} = \tilde{p}_t^{c^{-\theta^c}} Y_t^c mc_t^c + \beta_l \xi^c E_t \left[\frac{\lambda_{l,t+1}^c}{\lambda_{l,t}^c} \left(\frac{1}{\pi_{t+1}^c}\right)^{-\theta^c} \left(\frac{\tilde{p}_t^c}{\tilde{p}_{t+1}^c}\right)^{-\theta^c} x_{t+1}^{c,2}\right], \tag{1.42}$$

and

$$x_t^{c,1} = x_t^{c,2}, \tag{1.43}$$

where $\tilde{p}_t^c = \tilde{P}_t^c \big/ P_t^c$.

Given that the opportunity to reoptimize prices arrives probabilistically to each firm in each period, the aggregate price index (1.35) can be written in this recursive form:

$$1 = (1 - \xi^c) \left(\tilde{p}_t^c\right)^{1-\theta^c} + \xi^c \left(\frac{1}{\pi_t^c}\right)^{1-\theta^c}. \tag{1.44}$$

Durable Goods The dividend-maximizing problem of the durable good producers requires that they meet the following first-order necessary condition with respect to $\tilde{P}_t^d$:

$$E_t \sum_{s=0}^{\infty} \left(\beta_l \xi^d\right)^s \frac{\lambda_{l,t+s}^c}{\lambda_{l,t}^c} \frac{P_t^c}{P_{t+s}^c} \left[\left(1-\theta^d\right)\left(\frac{\tilde{P}_t^d}{P_{t+s}^d}\right)^{-\theta^d} Y_{t+s}^d + \theta^d \frac{MC_{t+s}^d}{P_{t+s}^d}\left(\frac{\tilde{P}_t^d}{P_{t+s}^d}\right)^{-\theta^d-1} Y_{t+s}^d\right] = 0.$$

where this expression has the same interpretation as in the case of non-durable goods production sector. To write this expression in recursive form, we follow the same strategy as in the non-durable goods production sector. This yields

$$x_t^{d,1} = \frac{\theta^d - 1}{\theta^d}\left(\frac{\tilde{q}_t}{q_t}\right)^{-\theta^d} Y_t^d + \beta_l \xi^d E_t \left[\frac{\lambda_{l,t+1}^c}{\lambda_{l,t}^c}\left(\frac{1}{\pi_{t+1}^c}\right)^{1-\theta^d}\left(\frac{\tilde{q}_t}{\tilde{q}_{t+1}}\right)^{-\theta^d} x_{t+1}^{d,1}\right], \tag{1.45}$$

$$x_t^{d,2} = \left(\frac{\tilde{q}_t}{q_t}\right)^{-\theta^d-1} Y_t^d \frac{mc_t^d}{q_t} + \beta_l \xi^d E_t \left[\frac{\lambda_{l,t+1}^c}{\lambda_{l,t}^c}\left(\frac{1}{\pi_{t+1}^c}\right)^{-\theta^d}\left(\frac{\tilde{q}_t}{\tilde{q}_{t+1}}\right)^{-\theta^d-1} x_{t+1}^{d,2}\right], \tag{1.46}$$

and

$$x_t^{d,1} = x_t^{d,2}, \tag{1.47}$$

where $\tilde{q}_t$ is the optimal real relative price of durable goods chosen by firms that have the opportunity to reoptimize in t.

Equation (1.35), the sectoral price index, satisfies this recursion for the durable goods production sector:

$$q_t^{1-\theta^d} = \left(1-\xi^d\right)\tilde{q}_t^{1-\theta^d} + \xi^d\left(\frac{q_{t-1}}{\pi_t^c}\right)^{1-\theta^d}. \tag{1.48}$$

For future reference, the durable goods gross inflation rate is $\pi_t^d = \frac{q_t}{q_{t-1}}\pi_t^c$.

1.4.1.4 Monetary policy

The central bank implements the Taylor-type (Taylor, 1993) monetary policy rule with interest smoothing:

$$\log\left(\frac{R_t}{R}\right) = \rho_r \log\left(\frac{R_{t-1}}{R}\right) + \rho_\pi \log\left(\frac{\pi_t}{\pi}\right) + \rho_y \log\left(\frac{Y_t}{Y}\right) + \varepsilon_t^R. \tag{1.49}$$

The monetary authority adjusts the nominal interest rate R_t from its steady-state value in response to deviations of inflation π_t from its target, and deviations of the GDP, Y_t, from its steady state value. ρ_r, ρ_π and ρ_y are the persistence parameter, and the inflation and output response parameters, respectively. The monetary policy innovation ε_t^R is composed of unanticipated and anticipated components:

$$\varepsilon_t^R = \epsilon_t^0 + \epsilon_{t-1}^1 + \epsilon_{t-2}^2 + \epsilon_{t-3}^3 + \epsilon_{t-4}^4,$$

where the notation follows the description of Section 1.2, and $\epsilon_t^i \sim N(0, \sigma_{\epsilon^i}^2)$, for $i \in \{0, 1, 2, 3, 4\}$. The notation ϵ_{t-i}^j, $\forall i, j$, means that the anticipated disturbances (or news shocks) learnt in $t - i$ will affect the economy in j periods ahead (i.e. we learn in $t - i$ a news that will happen in $t - i + j$).

1.4.1.5 Exogenous processes

Both sector-specific total factor productivities, z_t^c and z_t^d, follow an AR(1) process. For $j \in \{c, d\}$, z_t^j follows:

$$\log\left(\frac{z_t^j}{z^j}\right) = \rho_{z^j} \log\left(\frac{z_{t-1}^j}{z^j}\right) + \varepsilon_t^{z^j}, \tag{1.50}$$

where z^j is the steady-state values of the sector-specific total factor productivity, and the innovations $\varepsilon_t^{z^j} \sim N\left(0, \sigma_{\varepsilon^{z^j}}^2\right)$.

1.4.1.6 Market clearing and Aggregation

The aggregation in production and labour markets follows familiar steps from the New Keynesian literature. Integrating both sides of the intermediate goods production technology (1.36), we obtain

$$\int_0^1 Y_{m,t}^j dm = \int_0^1 z_t^j \left(l_{l,m,t}^j\right)^\omega \left(l_{b,m,t}^j\right)^{1-\omega} dm = z_t^j \left(l_{l,t}^j\right)^\omega \left(l_{b,t}^j\right)^{1-\omega}. \tag{1.51}$$

Substituting $Y^j_{m,t}$ in (1.51) and using demand function (1.34), we get

$$\left[\int_0^1 \left(\frac{P^j_{m,t}}{P^j_t}\right)^{-\theta^j} dm\right] Y^j_t = s^j_t Y^j_t = z^j_t \left(l^j_{l,t}\right)^{\omega} \left(l^j_{b,t}\right)^{1-\omega}, \tag{1.52}$$

where s^j_t captures the inefficiencies associated with price dispersion arising from the price rigidity *à la* Calvo (1983). Schmitt-Grohé and Uribe (2007) show that these price dispersion indexes can be represented as

$$s^c_t = (1-\xi^c)\left(\tilde{p}^c_t\right)^{-\theta^c} + \xi^c \left(\frac{1}{\pi^c_t}\right)^{-\theta^c} s^c_{t-1}, \tag{1.53}$$

and

$$s^d_t = \left(1-\xi^d\right)\left(\frac{\tilde{q}_t}{q_t}\right)^{-\theta^d} + \xi^d \left(\frac{q_{t-1}}{q_t}\right)^{-\theta^d} \left(\frac{1}{\pi^c_t}\right)^{-\theta^d} s^d_{t-1}. \tag{1.54}$$

The market clearing conditions for the two production sectors are therefore

$$Y^c_t = c_{l,t} + c_{b,t} = \frac{1}{s^c_t} z^c_t \left(l^c_{l,t}\right)^{\omega} \left(l^c_{b,t}\right)^{1-\omega}, \tag{1.55}$$

and

$$Y^d_t = i_{l,t} + i_{b,t} = \frac{1}{s^d_t} z^d_t \left(l^d_{l,t}\right)^{\omega} \left(l^d_{b,t}\right)^{1-\omega}. \tag{1.56}$$

The real aggregate output, i.e. real GDP, is therefore $Y_t = Y^c_t + q_t Y^d_t$, while the aggregations of the labour markets are $l^c_t = l^c_{l,t} + l^c_{b,t}$ and $l^d_t = l^d_{l,t} + l^d_{b,t}$, and the bond market is in zero net supply $b_{l,t} = -b_{b,t}$.

Finally, the price index for aggregate final goods $x_{l,t}$ and $x_{b,t}$ is given by

$$P_t = \frac{P^c_t Y^c_t + P^d_t Y^d_t}{Y^c_t + Y^d_t} \tag{1.57}$$

and the aggregate gross inflation rate is $\pi_t = \frac{P_t}{P_{t-1}}$.

1.4.1.7 Competitive Equilibrium

An (imperfectly) competitive equilibrium is an allocation for :

- the lenders: $\mathcal{C}_l = \left\{c_{l,t}, d_{l,t}, l^c_{l,t}, l^d_{l,t}, b_{l,t}\right\}_{t=0}^{\infty}$,
- the borrowers: $\mathcal{C}_b = \left\{c_{b,t}, d_{b,t}, l^c_{b,t}, l^d_{b,t}, b_{b,t}\right\}_{t=0}^{\infty}$,
- the firms in non-durable goods sector: $\mathcal{F}^c = \left\{Y^c_{m,t}, l^c_{l,m,t}, l^c_{b,m,t}\right\}_{t=0,m\in\{0,1\}}^{\infty}$,
- the firms in durable goods sector: $\mathcal{F}^d = \left\{Y^d_{m,t}, l^d_{l,m,t}, l^d_{b,m,t}\right\}_{t=0,m\in\{0,1\}}^{\infty}$, and
- prices system: $\mathcal{P} = \left\{R_t, P^c_{m,t}, P^d_{m,t}, \tilde{P}^c_t, \tilde{P}^d_t, \pi_t, \pi^c_t, \pi^d_t, w^c_{l,t}, w^c_{b,t}, w^d_{l,t}, w^d_{b,t}\right\}_{t=0}^{\infty}$,

such that, given initial conditions $d_{l,-1}$, $b_{l,-1}$, $d_{b,-1}$, $b_{b,-1}$, P_{-1}, P^c_{-1}, P^d_{-1}, s^c_{-1}, s^d_{-1}, R_{-1}, z^c_{-1} and z^d_{-1} and the prices system, the allocations $\mathcal{C}_l$, $\mathcal{C}_b$, $\mathcal{F}^c$ and $\mathcal{F}^d$ solve the households and firms problems, and all market clearing conditions in Section 1.4.1.6 are satisfied.

1.4.2 Calibration and Solution Method

Our solution method consists in taking a log-linear approximation of the equilibrium conditions in the neighborhood of the deterministic steady state. This local approximation method is accurate to the extent that we limit the exogenous processes to be bounded in the neighborhood of the steady state, an assumption which appears reasonable at least in the case of monetary policy shocks. The solution is then obtain using QZ decomposition (Klein, 2000; Sims, 2002).[25]

This model is calibrated at quarterly frequency. Some parameter values are typical in business cycle literature. We assume that the steady-state rate of inflation in both sectors is zero. The steady-state real interest rate is pinned down by the saver's degree of time preference, β_l. We choose an annual rate of return of 4 percent. This implies $\left(\frac{1}{\beta_l}\right)^4 = 1.04$, which yields $\beta_l = 0.99$. As to the calibration of the borrower's time discount factor, we choose $\beta_b = 0.96$. This value is in range of other studies that estimated or calibrated this value (Krusell and Smith, 1998; Iacoviello, 2005; Iacoviello and Neri, 2010). Following Gomme and Rupert (2007), the quarterly depreciation rate of the durable good stock is set at 0.058, implying an annual depreciation rate of 21.3 percent. The parameter α in the composite index x is chosen so that the steady-state share of durable goods output

[25] Dynare has been used to solve the model. See http://www.dynare.org/.

in total output is 25 percent. The parameter σ is set to be 1 so that the elasticity of labour is unity, and the parameter ν is set so that steady-state labour supply is 0.33 for lenders and 0.36 for borrowers. Following Beaudry and Portier (2004), the elasticity of substitution between non-durable and durable goods, η is set at 0.2, implying a strong complementarity between the consumption of both type of goods. For the parameter ω, which is the lender's share of total labour income, we follow Iacoviello and Neri (2010) estimation results by setting it to be 0.79. We also follow Iacoviello and Neri (2010) by setting the loan-to-value ratio, χ, to be 0.85.

Table 1.2: Steady-State Values

Steady-State	Interpretation	Values
$4 \times (R-1)$	Interest Rate	0.041
π	Gross Inflation Rate	1
$\dfrac{c}{Y}$	Non-Durable Consumption Share of GDP	0.7506
$\dfrac{q \times Y^d}{Y}$	Durable Consumption Share of GDP	0.2494
$\dfrac{q \times (d_l + d_b)}{4 \times Y}$	Durable Stock as a Share of GDP	1.075
l_l	Total Hours Worked - Lenders	0.328
l_b	Total Hours Worked - Borrowers	0.361
z_c	TFP - Non-Durable Goods Sector	1
z_d	TFP - Durable Goods Sector	1

We follow Auray et al. (2009) estimation results by setting the autoregressive parameters in the productivity processes to be 0.95 and the innovations' standard deviations to be 0.048726 in non-durable goods sector and 0.077054 in durable goods sector. The steady-state values of z^c and z^d are both set to 1.

Following Auray et al. (2009) and Monacelli (2009), the parameters θ^j ($j \in \{c,d\}$) are both set to 8, which yields a steady-state mark-up of 15 percent for intermediate goods producers. We set the parameters ξ^c at 0.75 and ξ^d at 0.50 for the baseline specifications.

The calibration of the monetary policy rule parameters and the standard errors of unanticipated and anticipated monetary shocks is based on our estimation results in Table 1.1. The calibration and steady-state values are summarized in Tables 1.2 and 1.3.

Table 1.3: Calibrated Parameters

Parameters	Values
Households	
α	0.77
β_l	0.99
β_b	0.96
δ	0.058
η	0.2
ν	7.5
σ	1
Firms	
ω	0.79
ξ^c	0.75
ξ^d	0.50
θ^c	8
θ^d	8
Monetary policy	
ρ_r	0.8391
ρ_π	2.8049
ρ_y	2.6838
AR(1) processes	
ρ_{z^c}	0.95
ρ_{z^d}	0.95
Standard errors	
$\sigma_{\varepsilon^{z^c}}$	0.048726
$\sigma_{\varepsilon^{z^d}}$	0.077054
σ_{ϵ^0}	0.0158
σ_{ϵ^1}	0.0054
σ_{ϵ^2}	0.0070
σ_{ϵ^3}	0.0038
σ_{ϵ^4}	0.0020

1.4.3 Simulation Results

In the simulation results section, we focus on the dynamic effects of unanticipated and anticipated monetary policy shocks on key macroeconomic variables in our model.

1.4.3.1 Durable Spending Dynamics without Borrowing Constraints

We start by studying a benchmark case, namely a standard New Keynesian model without borrowing constraint augmented by the presence of a durable goods sector. This is a modified version of our two-agents model. To obtain such a benchmark model, it suffices to fix the Lagrange multiplier on borrowing constraints, $\lambda^b_{b,t}$, at 0 in equations (1.28) and (1.31), yielding

$$\lambda^c_{b,t} q_t - \beta_b (1-\delta) E_t \left[\lambda^c_{b,t+1} q_{t+1}\right] = \frac{\alpha^{\frac{1}{\eta}} d_{b,t}^{\frac{-1}{\eta}}}{(1-\alpha)^{\frac{1}{\eta}} c_{b,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} d_{b,t}^{\frac{\eta-1}{\eta}}},$$

and

$$\lambda^c_{b,t} = \beta_b R_t E_t \left[\frac{\lambda^c_{b,t+1}}{\pi^c_{t+1}}\right],$$

and setting $\beta_l = \beta_p$. This version of the model collapses to a standard representative-agent model. The co-movement problem between non-durable goods and durable goods consumption following an unanticipated monetary policy tightening with sticky non-durable goods prices and flexible durable goods prices is well known in literature. When durable prices are flexible, the response of durable spending to an unanticipated monetary policy shock is countercyclical and negatively correlated with non-durable spending. In contrast, the empirical evidence gathered in Section 1.3 suggests a strong procyclical response of durable goods consumption, a positive co-movement with non-durable goods consumption, and a much larger sensitivity of durable goods spending to policy shocks. See Figures 1.1 and 1.6 for the empirical evidence and Barsky et al. (2007) and Monacelli (2009) for discussion.

Figure 1.11 presents theoretical impulse responses to an anticipated monetary policy tightening perceived in $t = -4$ and coming into effect in $t = 0$, for two scenarios: one with sticky non-durable prices and flexible durable prices ($\xi^d = 0$), and one with sticky prices in both sectors (with the parametrization of Table 1.2). Both shocks are one standard deviation events, and the response are expressed as annualized percentage deviations from steady state. Under a news shock, variables moves in advance of the realization of the shock in $t = 0$.

The flexible durable prices case exhibits the same co-movement problem as following an unanticipated shock. Of particular interest is the fact that the aggregate output rise following an anticipated policy shocks, due to an increase in non-durable goods consumption. The logic works as follows. The news shocks implies that, in the future, the demand for non-durable goods will decline, thereby inducing a declining in production and marginal cost. Due to the nominal rigidities, intermediate goods firms are forward-looking and set their current price (if they are able to adjust) based on current and future expected marginal costs. Consequently, non-durable intermediate goods producers start lowering their price in advance of the news shocks realization (Figure 1.11). This pushes households to purchase more non-durable goods prior to the shock. On the other hand, durable goods prices are flexible. Firms do not need to adjust their price prior to a future demand adjustment following the realization of the shock. However, their marginal cost increase, due to the higher production in the non-durable goods sector, which drives wages in both sectors up. The relative price of durable goods increases, and causes a decline in demand. After the shock is realized, its become a monetary policy tightening, and the same well documented co-movement problem arises (Barsky et al., 2007; Monacelli, 2009).

The sticky durable prices case exhibits the right pro-cyclical co-movement between non-durable and durable production, with a reaction of durable goods production that is much more sensitive than that of non-durable goods. The increase in non-durable goods consumption works in the same way as in the flexible durable goods price case. However, the reaction of durables is the opposite, due to the price rigidity. The logic closely follows the one from the first case. The news shocks implies that, in the future, the demand for durable goods will decline, and the marginal cost will be lower. Intermediate goods firms are forward-looking and set their current price (if they are able to adjust) based on current and future expected marginal costs. Consequently, durable intermediate goods producers start lowering their price in advance of the news shocks realization, which pushes households to purchase more non-durables and durables prior to the shock. This causes an increase in production, in marginal cost and in real wages (not shown in Figure) in both sectors. After the realization of the shocks, a decline in both sector is observed, as if there was a monetary policy tightening (as shown in Barsky et al. (2007)).

Figure 1.12 presents theoretical impulse responses to an anticipated monetary policy tightening perceived in $t = -4$ and coming into effect in $t = 0$, and an unanticipated monetary policy tightening perceived in $t = 0$. While the path of the variables are reasonably similar starting in $t = 0$, after accounting for the difference in the standard deviation of each shocks (adjustment not shown in the Figure), the decline in production in both sectors is less pronounced when the monetary policy tightening is first announced in advance. Indeed, the economy has the time to adjust gradually to the announced policy tightening, thereby smoothing reactions.

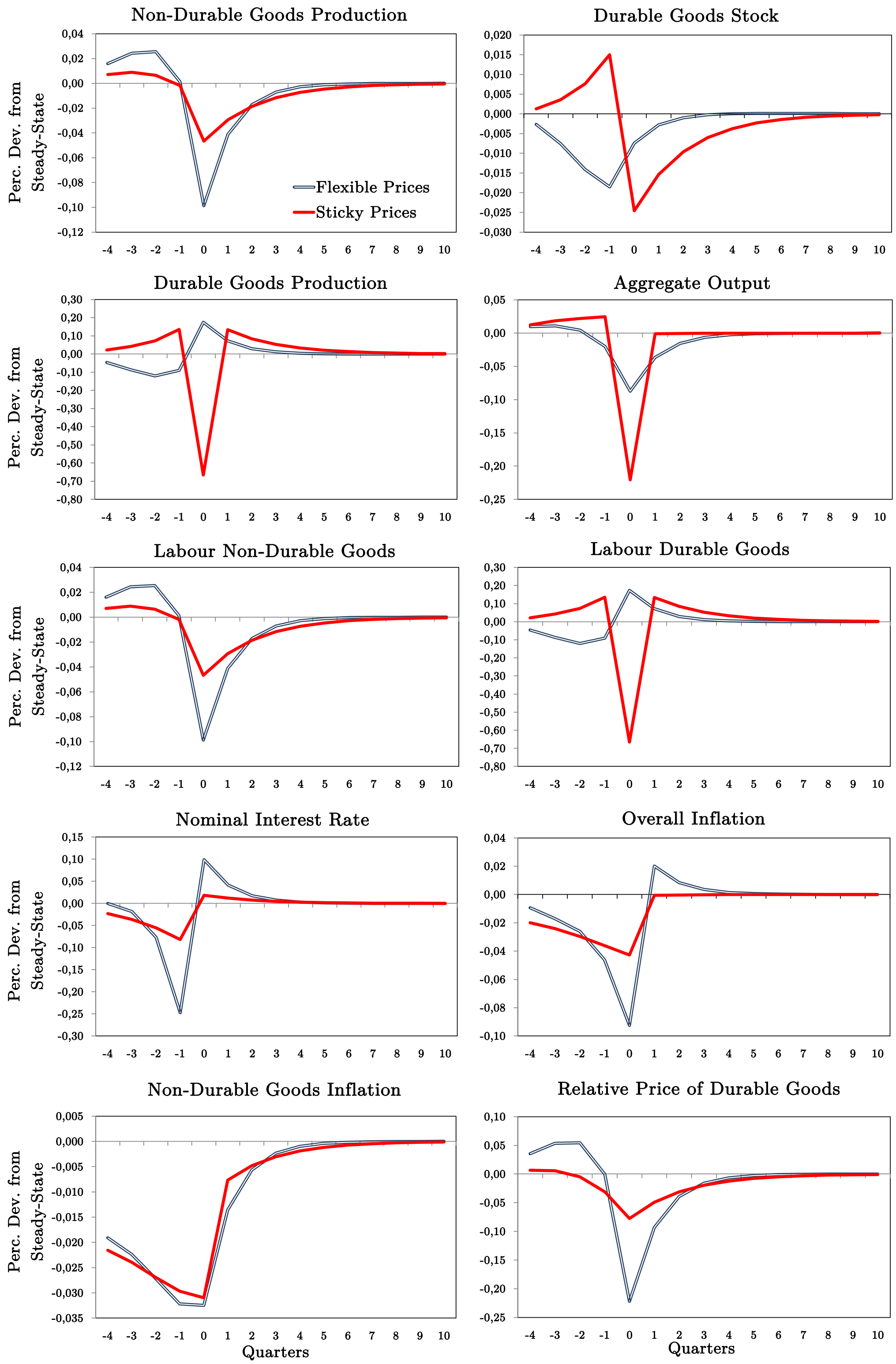


Figure 1.11: Theoretical Impulse Responses to Monetary Policy Anticipated Shocks Four Quarters Ahead - One Agent Model - Flexible vs Sticky Durable Goods Price

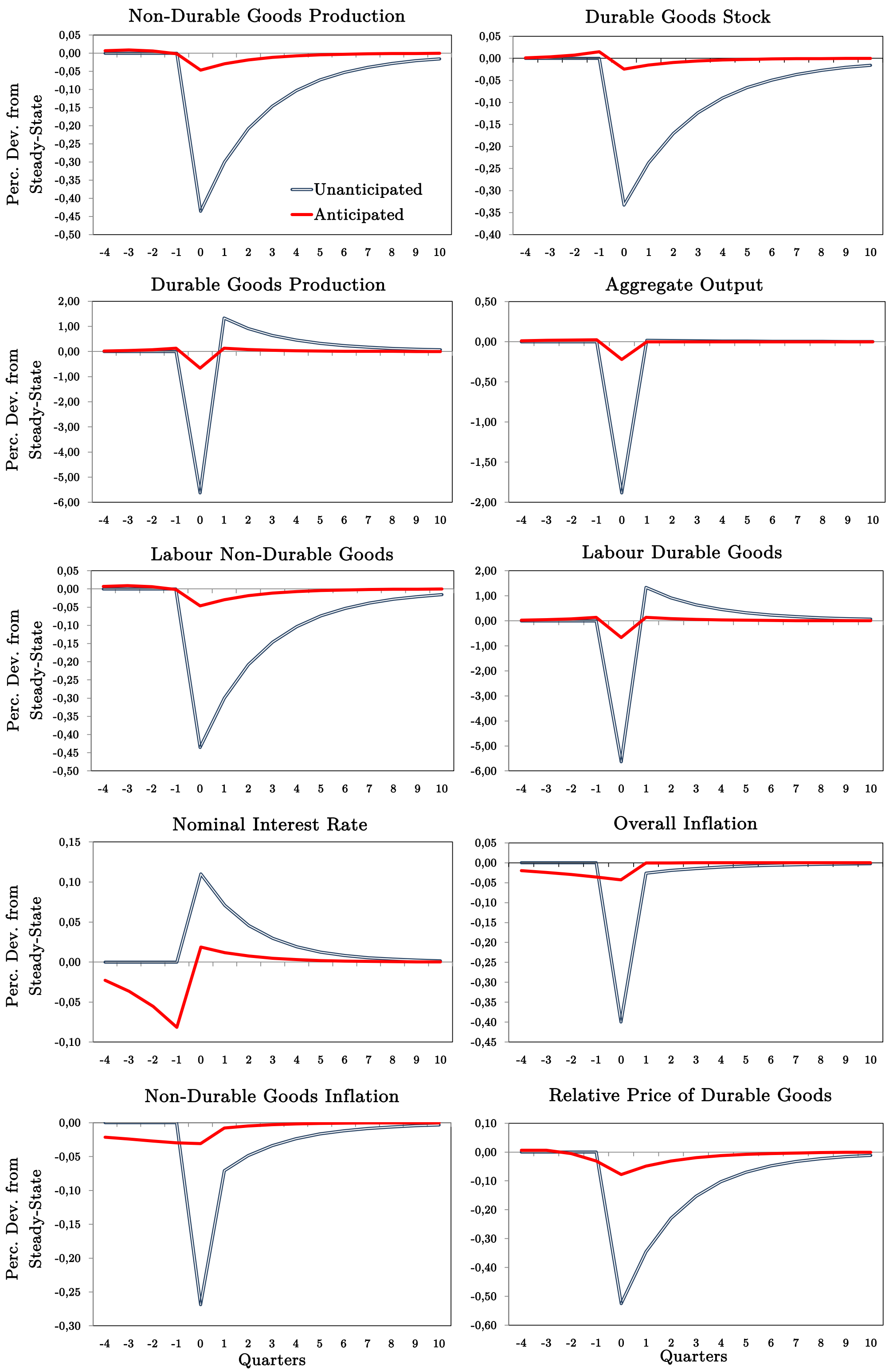


Figure 1.12: Theoretical Impulse Responses to Monetary Policy Unanticipated and Anticipated Shocks Four Quarters Ahead - One Agent Model - Sticky Durable Goods Price

1.4.3.2 Durable Spending Dynamics with Borrowing Constraints

In this subsection, we investigate the role of borrowing constraint. Figure 1.13 presents the total effect of news shocks on the production of non-durable goods and durable goods and on durable goods stock. The reallocation effect between lenders and borrowers is also illustrated. For each graph, theoretical impulse responses are provided for news shocks perceived in $t = -4$, $t = -3$, $t = -2$ and $t = -1$ and all coming into effect in $t = 0$.

As shown in Figure 1.13, the collateral effect of the borrowing constraint does not amplify the response of aggregate consumption of non-durable and durable goods to anticipated monetary shocks. In fact, the responses of both types of consumption are only marginally affected by the presence of collateral constraints. The reasons for this result is, in our view, twofold. First, the model ignores financing frictions on the side of the firms. Firms react the same way in setting their prices as in the one-agent model presented earlier. Their marginal costs are equally sensitive, and, since wages are equal across sectors for each type of agents, their pricing behavior will be the same as in the one-agent case. That is, they lower their prices in anticipation of future decline in demand. Indeed, our co-movement is generate because of this supply-side effect. While the decline in non-durable goods inflation is a VAR-based evidence of Section 1.3, the decrease in the relative price of durable goods is counterfactual.

Second, the lenders' share of total labour income (who are permanent income agents), is significant compared to credit constrained agents (borrowers). As shown in Figure 1.13, lenders drive most of the increase in both types of consumption. Despite a decline in interest rate (due to lower inflation), borrowers cannot borrow more. This is because their borrowing constraint also depends on the relative price of durable goods, which is increase in impact but declines afterwards. Eventually, the value of borrowers' collateral declines as a results of lower inflation, and induces an increase in the shadow value of borrowing. This causes first a stagnation, and a decline afterwards in the consumption of both non-durable and durable goods by the borrowers. By decreasing ω, the lenders' share of labour income, we can even generate an overall decrease in non-durable and durable goods consumption.

It is important to note that the collateral effects slightly reduces the sensitivity of durable production to monetary shocks. This is due to unconstrained households, which, in order to smooth their own consumption, shift loanable funds from the constrained households towards durable goods consumption. Finally, the negative response of the relative price of durables to monetary shocks mainly reflects nominal stickiness. The overall response of durable goods consumption is five to ten times larger than non-durable goods consumption, depending on the horizon of the news shocks.

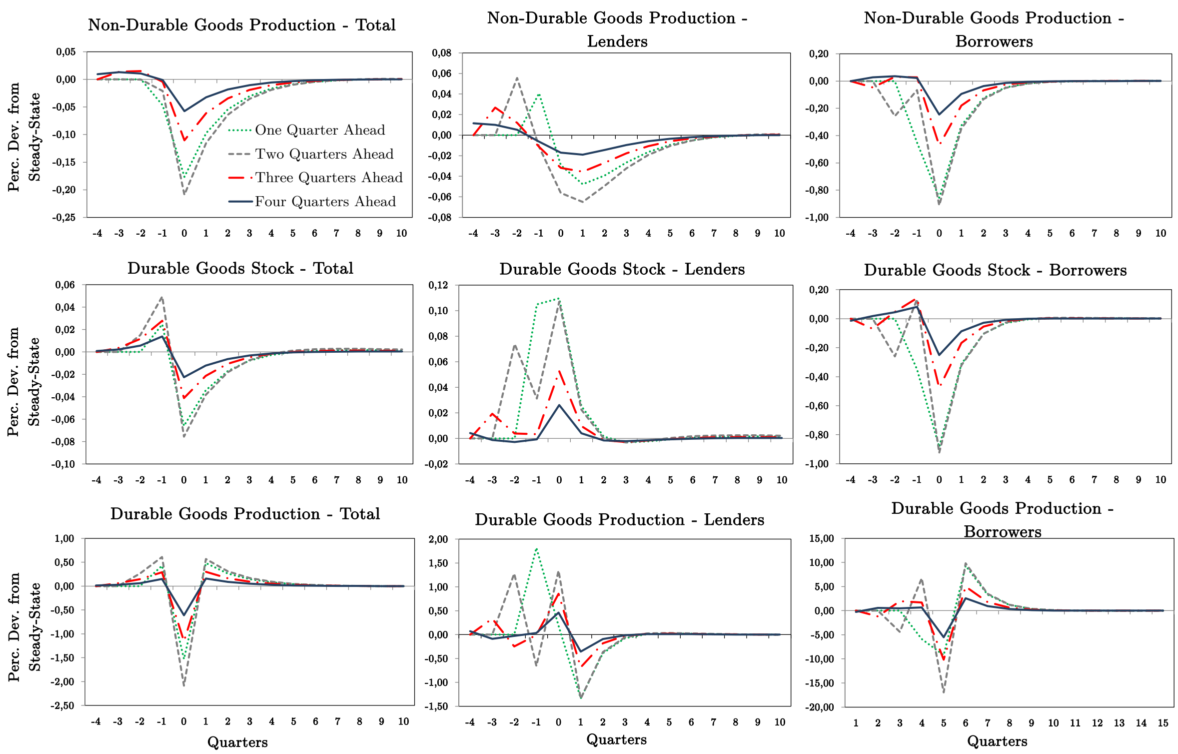


Figure 1.13: Theoretical Impulse Responses to Monetary Policy Anticipated Monetary Policy Shocks - Two Agents Model - Sticky Durable Goods Price

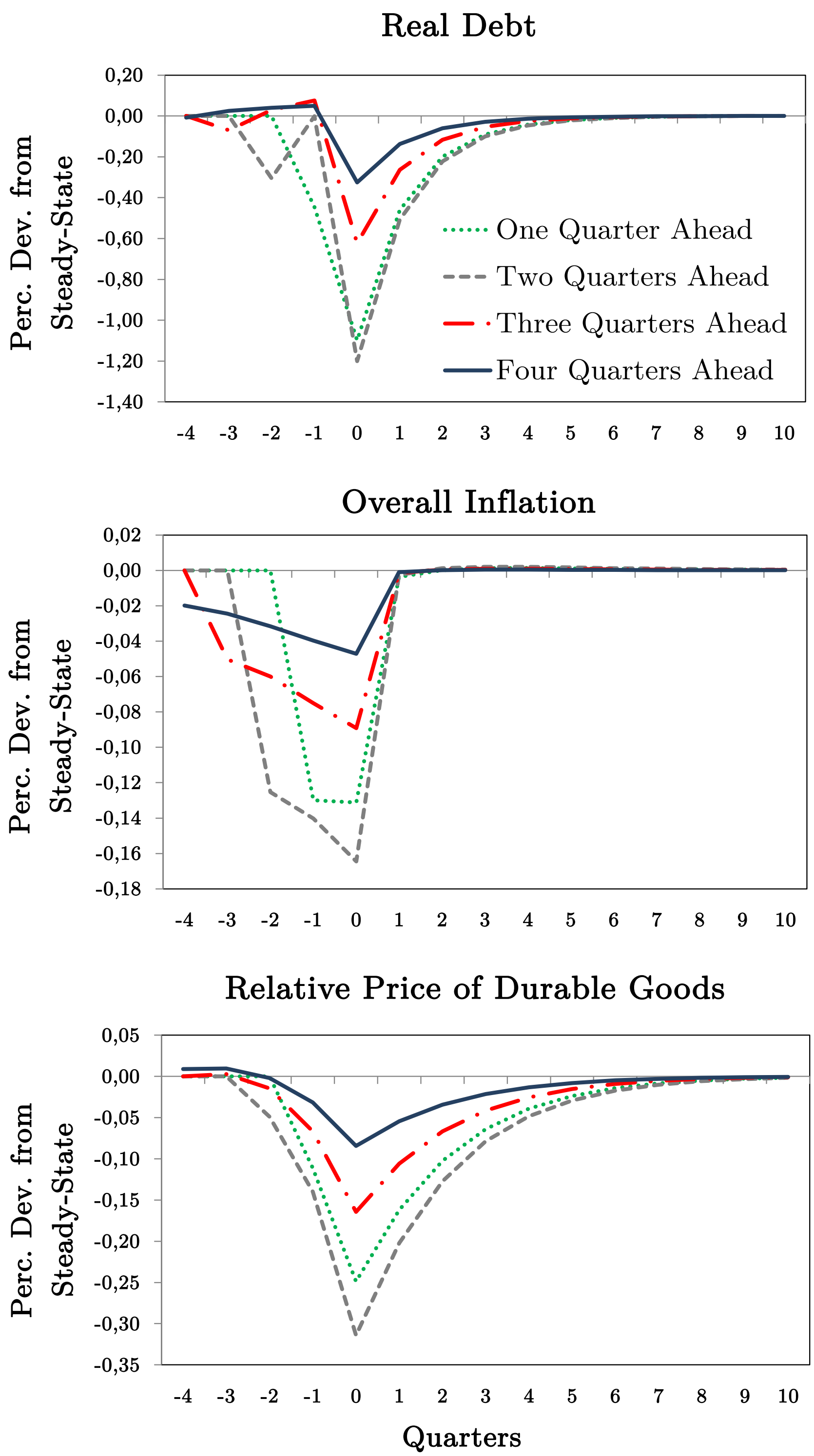


Figure 1.14: Theoretical Impulse Responses to Monetary Policy Anticipated Monetary Policy Shocks - Two Agents Model - Sticky Durable Goods Price

1.5 Conclusion

The main objective of this chapter was to disentangle the effects of unanticipated and anticipated monetary policy shocks on durable goods consumption. Extensive research has been done on the effects of unanticipated shocks on durable spending, while the effects of anticipated shocks had remained mainly unexplored. Given the importance of this question to the implementation of monetary policy, we have conducted empirical and theoretical analysis of this question.

In this chapter, the empirical analysis became possible thanks to our proposed approach to retrieving news shocks. We proposed and implemented a simple approach to the identification of news shocks about future monetary policy, where shocks are identified recursively from the residuals of a monetary policy rule estimated using survey data. We then used those inferred news shocks in a SVAR and found that an expected monetary policy tightening leads to an increase in output, non-durable and durable goods consumption, and real price of durable goods. Even though news shocks are responsible for a significant fraction of output and consumption fluctuations, they contribute less than anticipated shocks to economic fluctuations. Our theoretical analysis, based on a DSGE model with durable goods and nominal rigidities, showed that that a model with sticky durable goods price can cause non-durable and durable goods consumption to move together following a monetary policy news shocks, as found empirically with the SVAR.

To conclude, this chapter highlights interesting results about the link between monetary news shocks, durable and non-durable goods consumption, and structural macroeconomic factors. However, it is limited in the sense that it is silent about how news shocks are formed. Extensions of this work include giving a potential structural interpretation to the news shocks. They are potentially linked to announcements from the Federal Reserve, or economic news in general, like macroeconomic indicator releases. Future work should explore this possibility. Also, news shocks included in our model are considered to be uncorrelated contemporaneously and at all leads and lags. This is somehow an strong assumption. Future work could explore possible correlations between news shocks.

Finally, another interesting question is to evaluate whether a monetary policy rule that incorporates news shocks could be observationally equivalent to a time-variant rule of the Markov-switching or time-varying parameters type. Indeed, the implementation of a time-invariant rule with news shocks allows monetary authorities to deviate systematically from the rule for a certain period of time without affecting the reaction parameters.

Chapter 2

Exchange Rate Fluctuations and Labour Market Adjustments in Canadian Manufacturing Industries

with Kevin Moran

2.1 Introduction

The influence of exchange rates on Canadian manufacturing industries has attracted much attention historically and the recent period of continued appreciation of the Canadian dollar relative to its U.S. counterpart has proven no exception. The labour market response to this appreciation has drawn particularly strong interest, as concerns emerged that the higher value of the Canadian dollar would cause protracted declines in manufacturing jobs.

Figure 2.1 illustrates these concerns, by comparing the evolution of the real value of the Canadian dollar with that of total hours worked in manufacturing.[1] The figure shows that the real value of the Canadian dollar has experienced pronounced cycles of depreciation and appreciation over the last 40 years. These cycles appear to have been negatively

[1]The real effective exchange rate measure is from a database created by *Bruegel*, which computes real exchange rates for 178 countries over the span $1961-2010$. Nominal rates are deflated by pairwise relative CPIs and are weighted by trading importance. An increase represents an appreciation of the Canadian dollar. Hours worked is for all manufacturing industries and comes from the KLEMS database. Details on the data used in this chapter are presented below.

correlated with hours worked in manufacturing: for example, the 1990s were characterized by a steady depreciation of the Canadian dollar that bottomed out in 2002 and throughout this period, hours worked in manufacturing were increasing. Conversely, the more recent period has witnessed a rapid appreciation of the currency, at the same time as important retrenchments in manufacturing hours occurred.

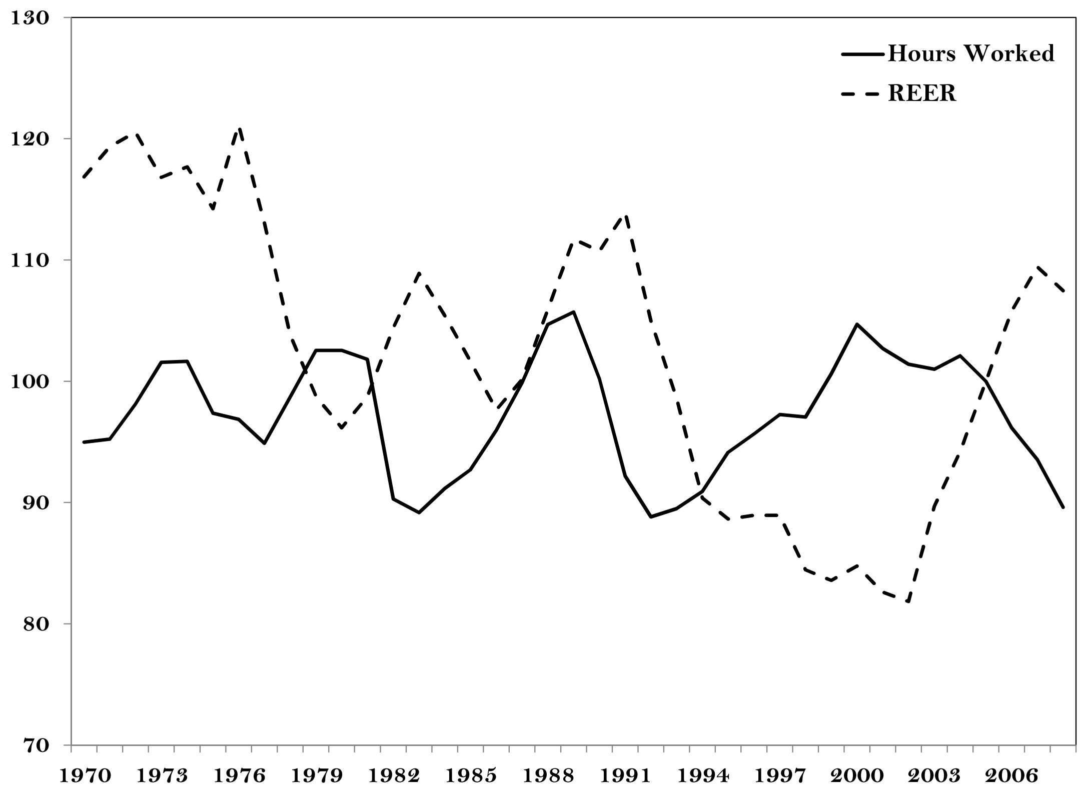


Figure 2.1: Real Effective Exchange Rate of the Canadian Dollar versus Hours Worked in Manufacturing (All Industries, 2005 = 100, 1970-2008).

This chapter provides a quantitative analysis of the link between exchange rate fluctuations and the labour input of manufacturing industries. Specifically, we ask the following questions. What are the long-term effects of changes to real exchange rates on manufacturing hours and jobs? How fast do the adjustments towards these long-term values take place? To address these questions, the chapter formulates a dynamic labour demand model and estimates it using KLEMS[2], an industry-level database of panel data organized

[2]KLEMS stands for **K**apital, **L**abour, **E**nergy, **M**aterial and **S**ervices.

under the North American Industry Classification System (NAICS). The data used to estimate our model spans from 1961 to 2008 and covers all major shifts in the real value of Canada's currency over the last 50 years.

We report four main findings. First, exchange rate fluctuations have sizeable effects on hours worked and jobs in Canadian manufacturing industries. Under our preferred model specification, a 10-percent real appreciation of the Canadian dollar is associated with a 3 percent reduction in hours worked and a decline just under 3 percent in jobs. Second, these adjustments occur relatively slowly: about 13 percent of the gap between actual and targeted labour (defined below) is closed each period (year). Third, these effects are stronger for industries with a high exposure to international trade. Fourth, important changes in the institutional landscape, notably the enactment of two major trade deals between Canada and its North-American partners have had significant negative impacts on the labour input of Canadian manufacturing firms.

An earlier contribution closely related to out study is Leung and Yuen (2007), who also study the impact of exchange rate fluctuations on the labour input of Canadian manufacturing firms. Two important features differentiate our study from the one by Leung and Yuen (2007). First, we use a substantially longer sample $(1961-2008)$ than the one that was available to them $(1981-1997)$. Our analysis thus covers all important shifts in the external value of the Canadian dollar during the modern era. Second, our longer dataset allows us to use an econometric methodology focusing on the long-term adjustments of manufacturing to shifts in exchange rates. Following this strategy, we start by estimating a cointegrating relation between the labour input of manufacturing firms, the real effective exchange rate, and other economic variables. When the cointegrating vector is established, we evaluate the speed of adjustment towards that long-term position. By contrast, Leung and Yuen (2007) abstracted from long-term adjustments and did not use cointegration techniques.

Other related work includes Campa and Goldberg (2001), who study the adjustment of United States manufacturing firms to U.S. dollar fluctuations but find no significant impact on employment and hours worked. This finding can be contrasted with Dekle (1998), who reports significant effects on Japanese manufacturing employment after changes in the external value of the yen. Burgess and Knetter (1998), studying a set of industrialized countries, show that exchange rate fluctuations have very small impacts on manufacturing employment in some countries, such as Germany and France, but have significant impacts in others, including the United States, Canada and the UK. None of these studies use econometric strategies able to control for cointegrated variables and to identify long-term adjustments.

This remainder of the chapter is organized as follows. Section 2.2 presents the theoretical model and the empirical specification. Section 2.3 introduces the data employed in the estimation, which is taken from the most recent release of the KLEMS database. Section 2.4 discusses estimation issues and our econometric strategy, while Section 2.5 reports our estimation results. Section 2.6 discusses our results and concludes. A detailed description of all data used and industry classification is provided in the appendices.

2.2 Model

This section develops an econometric model to analyze the long- and short-term impacts of exchange rate fluctuations on the labour input of Canadian manufacturing firms. The model assumes that Canada's manufacturing firms operate in monopolistically competitive environments in both their domestic and foreign markets. Accordingly, firms maximize profits by choosing their product's relative price, subject to a production function, input prices for which they are price-takers, and labour adjustment costs.

In this context, assume that worldwide demand for the product of firm i is expressed as

$$y_{i,t}^{d} = x_{i,t} p_{i,t}^{-\theta}, \tag{2.1}$$

where $p_{i,t}$ is the firm's relative price, θ is the price elasticity of demand, and $x_{i,t}$ indexes the overall demand for goods. The product-demand shifter $x_{i,t}$ first depends on the real exchange rate s_t between Canada and its trading partners. An increase in s_t represents a real appreciation, that reduces the ability of domestic firms to export profitably and allows foreign imports to enter more easily in Canada: we therefore expect s_t to have a negative impact on $x_{i,t}$. Next, $x_{i,t}$ depends on worldwide demand for Canadian goods y_t^{all}, which we measure by an aggregate of Canada's GDP and that of its trading partners.[3] We expect a positive impact from y_t^{all}. Finally, we allow $x_{i,t}$ to be affected by the enactment of two major trade agreements (the Canada-US Free Trade Agreement in 1989 and the North American Free Trade Agreement in 1994) as well as the switch to floating exchange rates between the Canadian and U.S. dollars in the 1970s.

Next, assume that the production function for firm i is

$$y_{i,t} = a_{i,t} F\left(l_{i,t}, k_{i,t}, ii_{i,t}\right), \tag{2.2}$$

where $a_{i,t}$ is multifactor productivity in industry i at time t, $l_{i,t}$ is a (quality-weighted) labour input, $k_{i,t}$ is the capital input, $ii_{i,t}$ is the input of intermediate goods, and $F(\cdot)$ is a constant returns-to-scale production function.[4] The price of labour in industry i is denoted by $w_{i,t}$, while the prices for capital and intermediate inputs are $p_{i,t}^K$ and $p_{i,t}^{II}$, respectively.

Consider first the frictionless level of labour, when no adjustment costs are present. Maximizing profits subject to (2.1) and (2.2) yields the following expression:

$$\begin{aligned} \ln l_{i,t}^* \quad = \quad & \alpha_{i,0} + \alpha_1 \ln w_{i,t} + \alpha_2 \ln p_{i,t}^K + \alpha_3 \ln p_{i,t}^{II} + \alpha_4 \ln a_{i,t} + \alpha_5 \ln s_t + \\ & \alpha_6 \ln y_t^{all} + \alpha_{i,7} CUSFTA_t + \alpha_{i,8} NAFTA_t + \alpha_{i,9} FEX_t + \varepsilon_{i,t}^{LT}, \end{aligned} \tag{2.3}$$

where $CUSFTA_t$ and $NAFTA_t$ are time dummies controlling for the two trade agreements while FEX_t indexes the transition towards floating exchange rates in the 1970s.[5]

[3]The notation y_t^{all} reflects the sum of Y_t and Y_t^* in Appendix 2.3, respectively the domestic and foreign demand. Our empirical work measures y_t^{all} as the $G7$ aggregate of real GDPs produced by the OECD. However, our results are robust to alternative measures of world demand for Canada's manufacturing products.

[4]Constant returns-to-scale production function is the hypothesis underlying the construction of KLEMS database.

[5]Specification in earlier versions of the paper included industry-specific linear time trend, to account for the possibility of secular decline in manufacturing sector activities. Results were quantitatively similar.

Appendix C describes how to obtain (2.3) in the case of a two-input, CES production function. It shows that the own-price elasticity parameter α_1 must be negative, but that the signs of α_2 and α_3 can vary according to the strength of substitution between labour and other inputs. Appendix C also shows that $\alpha_4 > 0$, $\alpha_5 < 0$ and $\alpha_6 > 0$.[6]

Starting with Nickell (1987), a large literature has assumed that adjustment costs prevent the frictionless labour input $l^*_{i,t}$ in (2.3) to be obtained. Instead, this literature (Burgess and Knetter, 1998; Dekle, 1998; Campa and Goldberg, 2001; Leung and Yuen, 2007) derives a partial adjustment process towards the long-run "target" labour input $l^*_{i,t}$, as in

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu) \ln l^*_{i,t},$$

or, written differently,

$$\Delta \ln l_{i,t} = -(1-\nu)\left(\ln l_{i,t-1} - \ln l^*_{i,t}\right), \tag{2.4}$$

where $(1-\nu)$ is the speed of adjustment towards the long-run targeted labour input.

Since our data are shown to be integrated and cointegrated, a natural interpretation of equations (2.3) and (2.4) is that of a cointegrating relation with an error-correction mechanism. Accordingly, our econometric strategy, discussed in detail below, involves first estimating the long-run relationship (2.3) and then the following, generalized version of (2.4):

$$\Delta \ln l_{i,t} = -(1-\nu)\left(\ln l_{i,t-1} - \ln l^*_{i,t}\right) + \sum_{s=1}^{p} \delta^y_{s,i} \Delta \ln l_{i,t-s} + \sum_{s=0}^{p} \delta^X_{s,i} \Delta \ln X_{i,t} + \varepsilon^{ST}_{i,t}, \tag{2.5}$$

where $X_{i,t} = \{w_{i,t}, p^K_{i,t}, p^{II}_{i,t}, a_{i,t}, s_t, y^{all}_t\}$. As discussed below, our estimation strategy uses the methods described in Breitung (2005) and Pesaran et al. (1999), which allow the intercepts (and other coefficients on deterministic regressors), short-run coefficients and error variances to differ across industries, but constrain the long-run coefficients to be the

[6]Note that the coefficients on prices and aggregate variables are common across industries while the time dummies are allowed to have industry-specific effects.

same.[7]

2.3 Data

To estimate equations (2.3) and (2.5), we construct a balanced panel of annual data for the Canadian manufacturing sector. The database includes both industry-specific and aggregate data and spans from 1961 to 2008[8].

The industry-specific data is from the KLEMS database. KLEMS, from Statistics Canada's Canadian Productivity Accounts, provides annual data on prices and quantities of output, as well as of capital, labour and intermediate inputs for all Canadian industries. The database is organized under the NAICS and the data we use pertain to the 20 manufacturing industries[9], at the 3-digit industry level. Specifically, KLEMS provides us with data for the quality-weighted labour input $l_{i,t}$, the hours worked $h_{i,t}$, the number of jobs $j_{i,t}$, the multifactor productivity $a_{i,t}$, and, when used in combination with the Industrial Product Price Indexes, the relative price of labour $w_{i,t}$, the relative user cost of capital $p^K_{i,t}$, the relative price of intermediate inputs $p^{II}_{i,t}$ (a weighted average of relative prices of energy $p^E_{i,t}$, materials $p^M_{i,t}$, and services $p^S_{i,t}$) for all industries $i = 1, \ldots, N$ with $N = 20$ and for all time period $t = 1, \ldots, T$ with $T = 48$. A complete description of these variables is provided in Appendix 2.1.[10]

Our empirical analysis makes uses of the three alternative measures of the labour input from KLEMS: $l_{i,t}$, $h_{i,t}$, and $j_{i,t}$. First, $h_{i,t}$ represents a simple sum of the hours worked for all workers in industry i. Next, $l_{i,t}$ provides a quality-weighted sum of hours that controls for the education and experience of the workers; our benchmark results are based on this measure. Finally, the variable $j_{i,t}$ represents total jobs in the sector, without controlling

[7]The existing literature on dynamic labour input adjustments (Burgess and Knetter, 1998; Dekle, 1998; Campa and Goldberg, 2001; Leung and Yuen, 2007) does not recognize the presence of cointegrating relationship between variables. In consequence, contributions to this literature generally estimate adjustment processes similar to (2.5) but without cointegration vectors and error correction mechanisms.

[8]2008 is the last date available for the KLEMS database

[9]The NAICS code 313 and 314 are aggregated in the KLEMS database.

[10]Since the KLEMS database only reports net change, it does not allow us to investigate the intra-industry reallocation of labour.

for age, skill level, education, or whether the positions are full- or part-time.[11] Using three different measures of labour can help ascertain whether exchange rate fluctuations impact the structure of the labour market, the labour force composition by class of workers, or the importance of the extensive (the numbers of jobs with no consideration for the number of hours worked) versus the intensive (hours worked) margins.

The real effective exchange rate, s_t, is a weighted sum of the exchange rates between the Canadian dollar and the currencies of its major trading partners; the weights are linked to the share of each partner in Canada's international trade and each nominal exchange rate is deflated by the country's CPI relative to Canada. An increase in s_t represents a real appreciation of the Canadian dollar.[12]

As measure of world demand for Canadian manufacturing goods, y_t^{all}, we use the simple sum aggregate of $G7$ real GDPs evaluated at the purchasing power parity provided by the OECD. Finally, the trade agreement dummies, $CUSFTA_t$ and $NAFTA_t$, take the value 1 starting in 1989 and 1994, respectively, while the dummy variable for the transition towards floating exchange rate starts at 1976.[13]

The impact of exchange rate fluctuations on an industry's labour input should depend on its openness to trade, both in relation to exports (as currency depreciations facilitate sales in foreign markets) and to imports (so that the same depreciation reduces the competitiveness of foreign producers in domestic markets). To allow for this possibility, our empirical analysis carries out separate estimates for industries with high and low trade exposure. Our measure of trade exposure follows Dion (2000) and defines the *net trade exposure*

[11]The authors thank Jean-Pierre Maynard from Statistics Canada for providing us the jobs data. An earlier version of this work (Bruneau and Moran, 2012) used employment data from the Labour Force Survey (LFS) because the jobs data from KLEMS was not available at the time. Using a single data source (KLEMS) helps reduce possible biases arising from different variable definitions and measurement methods. It also allows us to extend our data coverage to 1961.

[12]Our exchange rate data is from *Bruegel*, a Brussels-based research organization. The IMF, the OECD and the BIS also maintain measures of real effective exchange rate that use a variety of strategies to deflate nominal exchange rates. Lafrance et al. (1998) provide a discussion about the relative merits of alternative measures of real effective exchange rate. Our results are robust to alternative deflating strategies.

[13]1976 marks the year of the Jamaica Accord ratifying the end of the Bretton Woods System and ushering freely floating exchange rates. A test for breaks using Hansen (1997), performed on our real exchange rate data, supports this choice of date for the switch from fixed to freely-floating rates for the Canadian dollar.

(NTE) of an industry as follows: exports as a share of production, less imported output as a share of production, plus competing imports as a share of the domestic market. The input-output tables for 2000 are used to calculate the NTE of each manufacturing industry. Manufacturing industries with an NTE above the manufacturing sector average are classified as high-NTE industries, while below-average industries are classified as low-NTE industries.

We also use an alternative classification based on *export intensity* (EI). We computed the export intensity of an industry as follows: exports as a share of production. Manufacturing industries with an EI above the manufacturing sector average are classified as high-EI sectors, while below-average industries are classified as low-EI sectors. Table 2.1 in Appendix 2.2 presents the resulting classification for the 20 manufacturing industries we study.

2.4 Econometric Methodology

Panel Data Estimation

The recent popularity of panel data estimation largely arises from the robustness it provides relative to pure time series models. As noted by Baltagi and Kao (2000), the econometrics of nonstationary panel data aims at combining the best of both worlds: the ability to account for nonstationary data from the time series and the increased data and power from the cross-section. For example, while undetected unit root behavior can lead to spurious inference in pure time series models, regression estimates in panel data remain consistent because the information contained in the independent cross section of the data leads to a stronger overall signal than in pure time series cases (Kao, 1999; Phillips and Moon, 2000).

Although the OLS estimators of the cointegrated vectors are super consistent, correctly assessing the order of integration of variables remains important to conduct inference, because the asymptotic distribution of panel estimators in the presence of unit roots and cointegration is non-standard and the classic t-test statistic diverges at the same rate as in time series (Kao and Chen, 1995; Pedroni, 1996; Kao and Chiang, 1999). In panel data models, the analysis is further complicated by the potential presence of heterogeneity, cross-section dependence and cross-section cointegration, and a proper limit theory must take into account the cross-section (N) and time (T) dimensions (Phillips and Moon, 1999).

Cross-Sectional Dependence

Cross-section dependence (CSD) in macroeconomic panel data has received much attention in the emerging panel time series literature. This type of correlation may arise from globally common shocks with heterogeneous impact across countries, from local spatial or spillover effects, or could be due to unobserved (or unobservable) common factors.[14] We use the Pesaran (2004) CD test to evaluate the cross-sectional dependence of our data, because this test has been shown to have good size and power for dynamic models with relatively small samples, and the test is robust to nonstationarity, parameter heterogeneity and structural breaks.[15] The test is based on the average of pair-wise correlation coefficients of the residuals from the estimation of the cointegrating vectors (2.3), and the null hypothesis is the absence of cross-sectional dependence. The results of this test for each of the three measures of labour ($l_{i,t}$, $h_{i,t}$ and $j_{i,t}$) are presented in Table 2.1. The CD statistics reported in the table provide strong evidence against the null hypothesis of cross-sectional independence. Our empirical analysis below thus allows for CSD.

Table 2.1: Cross-section Independence Tests

Variables	CD Statistics
$l_{i,t}$	9.4160***
$h_{i,t}$	11.2070***
$j_{i,t}$	10.4543***

[14]For a detailed discussion of the topic within cross-country empirics, see Eberhardt and Teal (2011).

[15]See Moscone and Tosetti (2009) for a survey and application of existing cross-section dependence tests.

Unit Roots

The first generation of panel unit root tests is based on the hypothesis of cross-sectional independency (Harris and Tzavalis, 1999; Maddala and Wu, 1999; Hadri, 2000; Choi, 2001; Levin et al., 2002; Im et al., 2003). This is an important limitation, since the application of such tests to series characterized by CSD leads to size distortions and low power (O'Connell, 1998; Banerjee et al., 2004; Strauss and Yigit, 2003). Unit root testing for panels with CSD is the subject of an active literature, with two main solutions being suggested: the first one relies on the factor structure approach (Choi, 2002; Bai and Ng, 2004; Moon and Perron, 2004; Pesaran, 2007)[16], while the second applies bootstrap algorithms to estimate the distribution of the statistic of interest conditional on the cross-sectional linkages (Chang, 2004; Smith et al., 2004; Cerrato and Sarantis, 2007; Palm et al., 2011).

To obtain results that are robust to both short- and long-run forms of CSD, we follow the method proposed by Palm et al. (2011) (henceforth the PSU tests). They consider block bootstrap versions of the pooled (Levin et al., 2002) and the group-mean (Im et al., 2003) unit root coefficients of a Dickey-Fuller (DF) test for panel data, denoted τ_p and τ_{gm} respectively, to test the null hypothesis of unit roots. These tests were originally proposed for a setting of no CSD beyond a common time effect. Asymptotic validity of the bootstrap tests is established in very general settings, including the case with dynamic interdependencies, presence of common factors and cointegration across units. Asymptotic properties of the tests are derived for T going to infinity and N fixed, which is also desirable for our purpose.

[16]See Gengenbach et al. (2010) for a recent review of these methods.

Table 2.2: Panel Unit Root Tests

Variables	Alternative hypothesis[a]					
	AR		ARD		TS	
	PSU Statistics[b]					
	τ_p	τ_{gm}	τ_p	τ_{gm}	τ_p	τ_{gm}
	In Level					
$l_{i,t}$	0.0470	0.0689	-1.1476	-2.4546	-5.4440	-6.3920
$h_{i,t}$	0.0016	0.0008	-0.4627	-3.0922	-5.4450	-6.4035
$j_{i,t}$	0.0073	0.0051	-0.6282	-3.0429	-4.8269	-5.9161
$w_{i,t}$	-0.3943***	-0.7774***	-4.0488	-3.3268	-13.6534*	-10.4193
$p_{i,t}^K$	-0.5195	-1.8080	-14.6724***	-10.7183***	-19.5103***	-15.2089***
$p_{i,t}^{II}$	-0.0203	-0.0245	-2.4284	-5.3988	-5.8259	-8.3034
$p_{i,t}^E$	-0.2622**	-0.3453*	-0.3895	-0.5686	-3.3972	-3.4839
$p_{i,t}^M$	-0.0159	-0.0382	-1.8101	-5.0881	-6.2390	-9.0470
$p_{i,t}^S$	-0.0350	-0.0295	-1.5947	-3.3666	-3.2534	-4.3229
$a_{i,t}$	0.0609	0.0617	-2.4385	-3.5310	-10.5190*	-11.2905
	In First Difference					
$\Delta l_{i,t}$	-31.4591***	-33.0463***	-34.6833***	-35.9453***	-37.4751***	-39.0133***
$\Delta h_{i,t}$	-31.9202***	-33.2735***	-34.6962***	-35.6555***	-37.3214***	-38.5410***
$\Delta j_{i,t}$	-28.8352***	-29.9558***	-31.4239***	-32.0825***	-34.0882***	-35.0889***
$\Delta w_{i,t}$	-51.0093***	-37.7268***	-52.9262***	-41.4130***	-53.8325***	-42.2980***
$\Delta p_{i,t}^K$	-56.7900***	-48.6512***	-56.9293***	-48.9657***	-57.3164***	-49.6188***
$\Delta p_{i,t}^{II}$	-41.7332***	-39.8642***	-42.9191***	-41.7212***	-43.5098***	-42.8130***
$\Delta p_{i,t}^E$	-30.5355***	-28.5817***	-34.6579***	-32.8047***	-35.0634***	-33.1537***
$\Delta p_{i,t}^M$	-41.3257***	-40.0516***	-42.9329***	-42.4331***	-43.5269***	-43.5632***
$\Delta p_{i,t}^S$	-32.6551***	-28.1143***	-33.1951***	-28.5020***	-34.4936***	-29.4180***
$\Delta a_{i,t}$	-46.5930***	-44.5988***	-50.0814***	-47.8970***	-51.0197***	-49.1208***

[a]The alternative hypothesis are an autoregressive model (AR), an autoregressive model with drift (ARD) and a trend-stationary model (TS).

[b]We resample the residuals vector 1000 times with a block bootstrap scheme with a block length (B) equal to $1.75T^{1/3}$ to generate pseudodata with the null hypothesis of unit roots. The two test statistics are calculated for each bootstrap replication, to get the approximated distribution of the statistics of interest.

The results for panel unit roots tests are presented in Table 2.2 for each cross-sectional variable, namely $l_{i,t}$, $h_{i,t}$, $j_{i,t}$, $w_{i,t}$, $p_{i,t}^K$, $p_{i,t}^{II}$, $p_{i,t}^E$, $p_{i,t}^M$, $p_{i,t}^S$ and $a_{i,t}$. For each variable, the tests is first conducted with respect to the level of the variable[17] and then with respect to the first difference[18]. The table shows that, for most variables, strong evidence of $I\left(1\right)$

[17]Not rejecting H_0 suggests that the variable is at least $I\left(1\right)$.

[18]Rejecting H_0 suggests the variable is at most $I\left(1\right)$.

behaviour exists, although the results are less conclusive for the relative price of capital $p_{i,t}^{K}$.[19] We complement this with Table 2.3, which provides the results of the augmented Dickey-Fuller (ADF) unit root tests for the aggregate variables s_t and y_t^{all}, which are not cross-sectional specific. We also find strong evidence of unit roots for these variables.[20]

Table 2.3: Unit Root Tests for Aggregate Variables

Variables	Alternative hypothesis[a]		
	AR	*ARD*	*TS*
	ADF Statistics[b]		
	In Level		
s_t	-0.1320	-1.9616	-2.7813
y_t^{all}	2.7307	-5.0412***	-2.4194
	In First Difference		
Δs_t	-4.4161***	-4.3654***	-4.3113***
Δy_t^{all}	-2.0364**	-3.8626***	-5.0686***

[a]The alternative hypothesis are an autoregressive model (*AR*), an autoregressive model with drift (*ARD*) and a trend-stationary model (*TS*).

[b]Optimal lag length chosen with the Akaike criterion.

Cointegration

The first generation of panel cointegration tests also tends to ignore CSD, or attempts to account for it by cross-section demeaning or by using observable common effects. There have been been several panel cointegration tests suggested (McCoskey and Kao, 1998; Kao, 1999; Pedroni, 1999, 2001, 2004; Westerlund, 2005). They all allow for various degree of heterogeneity in the cointegrating coefficients, but the null and alternative imply that all variables are either cointegrated or not cointegrated. There is no allowance for some variables to be cointegrated and others not. Moreover, it is often assumed that there exists at most one cointegrating relationship (cointegration rank $r = 1$) in the individual specific models. System approaches to panel cointegration test that allow for more than one

[19]We performed Pesaran (2007) CIPS* test with an optimal lag length chosen with the Akaike criterion to provide additional insight on the unit root behaviour of the relative price of capital. The test results (not shown) shows that evidence of $I(1)$ behaviour exists for $p_{i,t}^{K}$ for all three alternative hypotheses.

[20]Two other measures of the real effective exchange rate are discussed in Section 5.1. The ADF tests also indicate $I(1)$ behaviour for these two measures.

cointegrating relationship include the work of Larsson et al. (2001) and Breitung (2005) who develop a likelihood-ratio test, and Maddala and Wu (1999) who use Fisher (1932)'s results and propose an alternative approach to testing for cointegration in panel data by combining individual cross-section Johansen cointegration tests (Johansen, 1988, 1991) to obtain a test statistic for the full panel.

Recent contributions to the analysis of panel cointegration emphasize the importance of allowing for CSD, and the suggested solutions are similar to the panel unit roots case.[21] To obtain results that are robust to CSD of various forms, we implement the Fisher-Johansen cointegration test (denoted λ), which is based on the combinations of individual Johansen cointegration test statistics significance level (p-value) and has a χ^2 distribution under the cross-sectional independency hypothesis[22]. In the case of CSD, we do not have independent tests, hence the statistics λ does not have a χ^2 distribution and must be approximated by bootstrap, as proposed in Maddala and Wu (1999). We follow Bruneau (2015), who use the algorithm developed in Swensen (2006) for time series and extend it to panel case. Table 2.4 presents the test results for the null hypothesis of no cointegration against the alternative of a non-zero cointegration rank: it reveals strong statistical evidence in favour of cointegration for our panel. Moreover, tests conducted over all the possible cointegration rank (not shown) point to a rank between 1 and 3, depending on the model and specification. Our empirical analysis below thus accounts for multiple cointegrating vectors.

[21] See Di Iorio and Fachin (2009), Fachin (2007) and Westerlund and Edgerton (2007) for bootstrap approach applied to single cointegrating vector testing.

[22] If the tests statistics are continuous, the significance levels π_i, for $i = 1, \ldots, N$, are independent uniform $(0, 1)$ variables, and $-2 \ln \pi_i$ has a χ^2 distribution with 2 degrees of freedom. Using the additive property of the χ^2 variables, we get $\lambda = -2 \sum_{i=1}^{N} \ln \pi_i$ and λ has a χ^2 distribution with $2N$ degrees of freedom. See Maddala and Wu (1999) for more details.

Table 2.4: Panel Cointegration Tests

Variables	Models[a]				
	H2	*H1**	*H1*	*H**	*H*
	$Fisher - Johansen$ Trace Statistics[b]				
$l_{i,t}$	276.3102***	276.3102***	265.9311***	267.8339***	226.4481*
$h_{i,t}$	276.3102***	276.3102***	262.4638***	266.7166***	229.6565*
$j_{i,t}$	276.3102***	276.3102***	259.6667***	262.9424***	222.9833

[a]The models described the form of the deterministic components of the VEC(q) model (see Johansen (1988, 1991)): no intercept or trend in the cointegrating relations and no trend in the data (*H2*), intercepts in the cointegrating relations and no trend in the data (*H1**), intercepts in the cointegrating relations and linear trends in the data (*H1*), intercepts and linear trends in the cointegrating relations and linear trends in the data (*H**), intercepts and linear trends in the cointegrating relations and quadratic trends in the data (*H*).

[b]We resample the residuals vector 1000 times with a *iid* bootstrap scheme to generate pseudodata with the null hypothesis of no cointegration with an optimal lag order chosen by a Schwarz information criterion. The test statistics are calculated for each bootstrap replication, to get the approximated distribution of the statistics of interest. The maximum eigen value test (not shown) was also calculated and yields the same conclusion.

Estimation Method

Two popular techniques to analyze single-equation framework of cointegrated variables are the Fully Modified Ordinary Least Squares approach (Phillips and Hansen, 1990; Pedroni, 1996; Phillips and Moon, 1999) and the Dynamic Ordinary Least Squares approach (Saikkonen, 1991; Stock and Watson, 1993; Mark and Sul, 2003). Subsequent studies (Pedroni, 1996; Kao and Chiang, 1999; Phillips and Moon, 2000) show that these two techniques deliver unbiased estimators with standard normal distributions when applied to panel data. However, these estimators assume that explanatory variables are all $I(1)$ but not cointegrated.[23] This drawback can be avoided by using system approaches.

System approaches to panel cointegration allowing for more than one cointegrating relations include the work of Larsson et al. (2001), Groen and Kleibergen (2003) and Breitung (2005), who generalized the likelihood approach introduced in Pesaran et al. (1999). Breitung (2005) proposes a two-step estimation procedure that extends the Ahn and Reinsel

[23]If there is more than one cointegrating relations, then the variance-covariance matrix of residuals from the integrated process of the explanatory variables is singular and the asymptotic is no longer valid.

(1990) and Engle et al. (1991) approach from the time series to panel case. He considers a panel vector error-correction model set-up where only the cointegrating spaces are assumed to be identical for all cross-section members. In the first step of his procedure, the parameters (both long- and short-run) are estimated individually, and in the second step the common cointegrating space is estimated in a pooled fashion. The resulting estimator is asymptotically efficient and normally distributed. Since results from Monte Carlo simulation in Breitung (2005) and Wagner and Hlouskova (2010) suggest that the two-step estimator has a good performance, we use this estimation method.[24] Statistical inference is then based on Driscoll-Kraay-Newey-West standard errors (Driscoll and Kraay, 1998).

We use a two-stage least squares to estimate the industry-specific short-run relationship, to control for the potential endogeneity of $w_{i,t}$. In the first stage, the relative price of labour is regressed on all predetermined and exogenous variables in the model. The predicted values obtained from this regression is then used in the second stage.[25]

2.5 Results

This section presents our estimation results. First, Section 2.5.1 presents our estimates of the (long-term) cointegrating vector (2.3) and then Section 2.5.2 discusses the dynamic (error-correcting) adjustment process (2.5). Throughout, we report results obtained using all 20 manufacturing industries, as well as high- and low-NTE subsets of these industries. An extensive sensitivity analysis is provided, which explores the robustness of our results to alternative measures for the labour input, for the real effective exchange rate, for the openness to trade, and for the price of intermediate inputs. In all tables of results, estimates superscripted by *, **, or *** indicate significance at the 10 percent, 5 percent

[24] Even if there is more than one cointegrating relations in the panel, we estimate one relation. This estimated relation, in this case, still provide a consistent estimate of a cointegrating vector. Among the set of possible cointegrating relations, the two-step estimator selects the relation whose residuals are uncorrelated with any other $I(1)$ linear combinations of the explanatory variables (Hamilton, 1994).

[25] To facilitate the presentation of our results, the estimated industry-specific coefficients reported in the various tables (coefficients on time dummies reported in Tables 2.5 to 2.11 and all the coefficients in Tables 2.12 to 2.14) are the mean-group estimates, an aggregation of industry-specific estimated coefficients via an equally weighted linear combinations. However, all the simulations are conducted using the industry-specific estimated coefficients, not the mean-group estimate.

and 1 percent levels, respectively.

2.5.1 Long-term Effects (Cointegrating Vectors)

Benchmark Results

Table 2.5 presents our benchmark estimates of the cointegrating vector in expression (2.3). Most estimates are highly statistically significant and are consistent with our theoretical priors. Notably, the own-price elasticity (the effect of $w_{i,t}$ on labour input) is negative, while the impact of the price of capital ($p^K_{i,t}$) and that of the price of intermediate inputs ($p^{II}_{i,t}$) are positive, indicating substantial substitution between labour and other inputs. As suggested by theory, the coefficient of the real effective exchange rate is negative, indicating that an appreciation of the Canadian dollar is associated with a decrease in manufacturing's labour input, while the impact of world GDP (y^{all}_t) is positive. The enactment of the two trade agreements have negative impacts on the labour input, a result compatible with earlier work (Gaston and Trefler, 1997; Beaulieu, 2000), indicating that trade liberalization has improved productivity but lowered employment in Canadian manufacturing industries. Finally, the transition towards a floating exchange-rate regime is associated with a decrease in the labour input of manufacturing industries.

The results in Table 2.5 are also economically significant. The estimate for the real exchange rate is -0.3007, indicating that a 10-percent real appreciation of the exchange rate is associated with a 3-percent long-term decrease in the labour input $l_{i,t}$. This impact is stronger for high-NTE industries (0.3464, or a decrease of 3.5 percent following a 10-percent real appreciation) while it is negligible and not statistically significant for low-NTE industries.

Table 2.5: Cointegrating Vectors

Labour Input ($\ln l_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3642***	-0.2986**	-0.3204***
$\ln p_{i,t}^{K}$	0.0562***	0.1380***	-0.0266
$\ln p_{i,t}^{II}$	0.1899***	0.1605**	0.1981**
$\ln a_{i,t}$	0.1855	-0.0445	-0.1945
$\ln s_t$	-0.3007***	-0.3464***	-0.0224
$\ln y_t^{all}$	0.4785***	0.5259***	0.4286***
$CUSFTA_t$	-0.0529***	-0.0450***	-0.0818***
$NAFTA_t$	-0.1432***	-0.1573***	-0.0716**
FEX_t	-0.0957***	-0.0959***	-0.0533*

Note: Estimates of the cointegrating vector of expression (3) in the text, using the methods described in Breitung (2005) and Pesaran et al. (1999). The three columns depict estimates obtained for all, high- and low-NTE industries. The symbols *,** and *** indicate statistical significance of the coefficient at the 10%, 5% and 1% level, respectively, using Driscoll-Kraay-Newey-West standard errors. Estimated coefficients and statistical inference for $CUSFTA_t$, $NAFTA_t$ and FEX_t are mean-group estimates.

The impact of price of labour $w_{i,t}$ is also substantial and, at -0.3642, is estimated to be of similar magnitude to that of the real exchange rate. The prices of other inputs (the price of capital $p_{i,t}^{K}$ and the price of intermediate inputs $p_{i,t}^{II}$) have positive impacts of 0.0562 and 0.1899, respectively, suggesting that a substantial degree of substitution exists between labour and other inputs (See Appendix C for a discussion). The estimated impacts of $w_{i,t}$ and $p_{i,t}^{II}$ are of similar magnitude across industries but for the price of capital $p_{i,t}^{K}$, the "all industries" average is very different than the one for industries opened to trade (a strong positive effect) and for those are not (a negligible and not statistically significant impact).

Next, the impact of world GDP (y_t^{all}) is also important, with the benchmark estimate suggesting a 0.48-percent long-run decrease in the labour input for each 1-percent decline in global demand for Canada's manufacturing production. The effect again varies across openness to trade and is larger for high-NTE industries. The two trade agreements have statistically and economically significant impacts, with the enactment of NAFTA being associated with a 15-percent decrease in the labour input for high-NTE industries.[26] Fi-

[26]The magnitude of the coefficient associated with NAFTA could, however, also signal the growing importance of China on the world manufacturing scene starting in the mid-1990s.

nally, Table 2.5 indicates that productivity has a positive but not statistically significant impact on the labour input. According to the model sketched in Appendix C, this could suggest that Canadian manufacturing firms operate in environments with relatively low substitution across different goods.[27]

Overall, Table 2.5 shows that exchange rate movements have statistically and economically significant long-run effects on the labour input of Canada's manufacturing firms, with a 10-percent real appreciation being associated with a 3-percent decrease in labour. In addition, input prices, global demand, and the enactment of trade agreements also have substantial effects, and an industry's openness to trade is a key modifier to the magnitude of these impacts. The impact of real effective exchange rate might be even stronger than suggested by the results in Table 2.5. If a real appreciation of the Canadian dollar makes imported capital more expensive and in turns leads to substitution away from capital and towards labour, an additional effect would be induced. However, results in Table 2.5 suggest this added effect is likely to be small. Considering that across industries, roughly 1/6 of the capital input in our dataset is imported,[28] and that the estimated coefficient on the price of capital is relatively small (0.0562), the induced effect via imported capital (allowing for full pass-through of the appreciation into the Canadian price of imported capital[29]) would be $-0.0562 \cdot 1/6$ or around -0.01, a much smaller figure than the direct effect of -0.3007 in Table 2.5.

Sensitivity Analysis

To study the robustness of our results, we first repeat our estimation of the cointegrating vectors using alternative measures of the labour input. In this context, Tables 2.6 and 2.7 below present results obtained using hours worked ($h_{i,t}$) and jobs ($j_{i,t}$), respectively,

[27]An increase in productivity decreases marginal costs and, as a result, the price charged by the firm. The extent to which this price decrease results in a significant increase in demand – and a subsequent increase in labour demand – is governed by the elasticity of substitution across varieties. If this elasticity is low, the coefficient on productivity could be negligible (see Appendix C).

[28]In KLEMS, capital is a composite of machinery and equipment, structures, inventories and land inputs. Of those, only machinery and equipment has a significant imported component. The average imported component for the capital composite is estimated at 1/6 by Leung and Yuen (2005).

[29]Full pass-through is the hypothesis underlying the construction of the KLEMS data.

instead of the labour input (l_{i_t}). Recall that hours worked $h_{i,t}$ is a simple sum of hours worked with no control for skill and experience (as is the case for l_{i_t}), while $j_{i,t}$ is total number of jobs, again with no allowance to various work arrangements and experience differentials.

Table 2.6: Cointegrating Vectors
Hours Worked ($\ln h_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3604***	-0.3137**	-0.3053***
$\ln p^K_{i,t}$	0.0514**	0.1380***	-0.0381**
$\ln p^{II}_{i,t}$	0.2271***	0.1982***	0.2286**
$\ln a_{i,t}$	0.1967	-0.0529	-0.1077
$\ln s_t$	-0.3242***	-0.3541***	-0.0460
$\ln y^{all}_t$	0.3266***	0.3810***	0.2775***
$CUSFTA_t$	-0.0584***	-0.0422**	-0.1067***
$NAFTA_t$	-0.1698***	-0.1830***	-0.0936***
FEX_t	-0.0997***	-0.0961***	-0.0632*

Note: See note of Table 2.5.

Significant differences between the benchmark results of Table 2.5 and those arrived at using hours worked (Table 2.6) or jobs (Table 2.7) would suggest that changes to real exchange rates have compositional effects on the labour mix or on the organization of the workweek, in addition to the aggregate effects described above. Overall, however, results are qualitatively similar across the three tables. One quantitative difference does emerge, in Table 2.7, where the estimated coefficients on the real exchange rate are shown to be substantially smaller for jobs than those arrived at with the other two definitions of the labour input: -0.2691 relative to -0.3007 in the benchmark for all industries and -0.2796 relative to -0.3464 for high-NTE industries. Such a result suggests that a given appreciation of the real value of the Canadian dollar is associated with a smaller long-run decrease in jobs than in hours worked, indicating that both intensive and extensive margins respond to exchange rate movements. By contrast, the estimated magnitude of the impact for $CUSFTA$ is larger for jobs than it was for $l_{i,t}$ and $h_{i,t}$. Notwithstanding these differences, our results appear largely robust to the definition of the labour input.

Table 2.7: COINTEGRATING VECTORS
Jobs ($\ln j_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3133***	-0.2639*	-0.2598***
$\ln p^K_{i,t}$	0.0360	0.1287***	-0.0575***
$\ln p^{II}_{i,t}$	0.2869***	0.2228***	0.3146***
$\ln a_{i,t}$	0.2329	-0.0384	-0.1002
$\ln s_t$	-0.2691**	-0.2796***	-0.0198
$\ln y^{all}_t$	0.3481***	0.4044***	0.2967***
$CUSFTA_t$	-0.0963***	-0.0785***	-0.1487***
$NAFTA_t$	-0.1521***	-0.1656***	-0.0720**
FEX_t	-0.0831***	-0.0777***	-0.0475*

Note: See note of Table 2.5.

Next, Table 2.8 assesses the importance of our measure of trade openness. Recall that our benchmark results are based on the measure in Dion (2000), which controls for the importance of exports as a share of production and for imports as a share of the domestic market. By contrast, Table 2.8 uses data on *Export Intensity* (EI) only (from Industry Canada) to classify industries into high- and low-EI.[30]

Table 2.8: COINTEGRATING VECTORS
Export Intensity

Variables	Industries		
	All	High EI	Low EI
$\ln w_{i,t}$	-0.3642***	-0.1427	-0.4352***
$\ln p^K_{i,t}$	0.0562***	0.0882***	0.0786
$\ln p^{II}_{i,t}$	0.1899***	-0.1742	0.3007***
$\ln a_{i,t}$	0.1855	-0.8884***	0.7227**
$\ln s_t$	-0.3007***	-0.4815***	-0.0844
$\ln y^{all}_t$	0.4785***	0.8180***	0.1746*
$CUSFTA_t$	-0.0529***	-0.0708***	-0.0310*
$NAFTA_t$	-0.1432***	-0.1455***	-0.1142***
FEX_t	-0.0957***	-0.1088***	-0.0646**

Note: See note of Table 2.5.

This modification has important consequences on the magnitude and statistical significance of many estimates. First, the impact of the real exchange rate for industries highly

[30]The first column of Table 2.8, for all industries, naturally reproduces the benchmark results of Table 2.5.

opened to trade is now -0.4815, 50 percent stronger than -0.3007, its "all industries" counterpart (the coefficient for industries not opened to trade remains low and not statistically significant). This suggests that it is for exporting industries, more than for industries affected by trade via imports, that appreciation and depreciation cycles in the real value of the Canadian dollar have important impacts. Similarly, the influence of worldwide product demand (the impact of y_t^{all}) is almost double in industries highly opened to trade, relative to their "all industries" benchmark. Overall, the results in Table 2.8 support benchmark estimates, but single out exports as the key marker across which movements in exchange rate and product demand impact the labour input of Canada's manufacturers.

Continuing our robustness analysis, Tables 2.9 and 2.10 analyze alternative measures for the exchange rate. First, Table 2.9 presents results obtained using *nominal* effective exchange rates since movements in real exchange rates are often considered to be dominated by nominal rate changes (and only very gradual relative prices adjustments) these might be sufficient to measure the actual ability of domestic producers to export abroad profitably. By contrast, Table 2.10 retains the idea of deflating nominal exchange rates, but uses relative unit labour costs (RULC) to do so. This deflating strategy follows a literature arguing that using unit labour costs to deflate exchange rates is a suitable method to accurately capture Canada's ability to sell abroad profitably (Lafrance et al., 1998).

Table 2.9: Cointegrating Vectors
Nominal EER

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3649***	-0.2642*	-0.3434***
$\ln p_{i,t}^{K}$	0.0549***	0.1326***	-0.0248
$\ln p_{i,t}^{II}$	0.1666***	0.1273*	0.1889**
$\ln a_{i,t}$	0.1273	-0.1414	-0.1340
$\ln s_t$	-0.4375***	-0.5052***	-0.1141
$\ln y_t^{all}$	0.6107***	0.6629***	0.4784***
$CUSFTA_t$	-0.0426***	-0.0357**	-0.0806***
$NAFTA_t$	-0.1182***	-0.1216***	-0.0813***
FEX_t	-0.1145***	-0.1116***	-0.0689**

Note: See note of Table 2.5.

Alternative measures of exchange rates modify some of the quantitative results. Notably, the estimated coefficients on exchange rates increase in magnitude when nominal effective exchange rate is used (Table 2.9) but this magnitude is then decreased when using unit labour costs (Table 2.10). The pattern from Table 2.5, by which openness to trade increased this coefficient for high-NTE industries and reduced it to small, not statistically significant numbers for low-NTE industries remains in Tables 2.9 and 2.10. The impact of worldwide product-demand (y_t^{all}) similarly increases in Table 2.9 but is reduced in Table 2.10, relative to the benchmark results in Table 2.5.

Table 2.10: COINTEGRATING VECTORS
Real EER - RULC

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.3898***	-0.3236***	-0.3346***
$\ln p_{i,t}^K$	0.0752***	0.1524***	-0.0055
$\ln p_{i,t}^{II}$	0.1238***	0.0256	0.1831**
$\ln a_{i,t}$	0.3972***	0.1945	-0.0717
$\ln s_t$	-0.1383***	-0.1405*	-0.0029
$\ln y_t^{all}$	0.1797***	0.2207***	0.2476***
$CUSFTA_t$	0.0229**	0.0295**	-0.0384*
$NAFTA_t$	-0.0699***	-0.0771***	-0.0470**
FEX_t	-0.0316**	-0.0378**	-0.0166

Note: See note of Table 2.5.

Finally, Table 2.11 assess a decomposition of the price of intermediate goods $p_{i,t}^{II}$ into relative prices of energy $p_{i,t}^E$, of materials $p_{i,t}^M$ and of services $p_{i,t}^S$). Interestingly, this has the effect of reducing both the economic and statistical significance of exchange rate. Since, at the same time, the price of energy is found to be both negative and very substantial economically, this result is probably explained by the high correlation between energy prices and the exchange rate of the Canadian dollar over the last two decades.

Table 2.11: Cointegrating Vectors
Disaggregated p^{II}

Variables	Industries		
	All	High NTE	Low NTE
$\ln w_{i,t}$	-0.2672***	-0.2806**	-0.2082***
$\ln p_{i,t}^{K}$	0.0451**	0.1223***	-0.0334**
$\ln p_{i,t}^{E}$	-0.2502***	-0.2728***	-0.1218*
$\ln p_{i,t}^{M}$	0.1765***	0.1300**	0.1899***
$\ln p_{i,t}^{S}$	-0.0420	0.0058	-0.0908
$\ln a_{i,t}$	0.2769*	0.1274	-0.2072
$\ln s_t$	-0.1331*	-0.1203	0.0295
$\ln y_t^{all}$	0.5786***	0.6638***	0.4577***
$CUSFTA_t$	-0.0768***	-0.0761***	-0.0825***
$NAFTA_t$	-0.1183***	-0.1226***	-0.0647**
FEX_t	0.0079	0.0185	-0.0138

Note: See note of Table 2.5.

In summary, our estimates of the cointegrating relationship (2.3) reveal important and robust findings: exchange rates and worldwide demand for Canadian products exert powerful long-run influences on the labour input of manufacturing firms, and these effects are stronger for industries more opened to trade, particularly for exporters. Further, the enactment of two major trade agreements had an important negative effect on labour inputs. Finally, we find evidence that substantial levels of substitution exist between labour and other inputs, so that increases in the price of capital and intermediary inputs lead to increases in the labour input of manufacturing firms. The next subsection explores the characteristics of the dynamic adjustment to these long-run properties.

2.5.2 Dynamic Adjustment (Error-correcting Mechanism)

This subsection analyzes the adjustment towards the long-term cointegrating vector in (2.3). To this end, equation (2.5) is estimated via a two-stage least square framework that aims at correcting for possible problems of endogeneity between wages and labour input. A general-to-specific strategy is used to establish the number of lags p needed in (2.5) and the exchange rate is the only variable for which lagged values appear in a statistically significant manner. As a consequence, only the current values of wages, prices, productivity and world output appear in the three tables of results below, whereas for the exchange rate both current and lagged values are present.[31] Estimation results are provided in Table 2.12 (for labour input), Table 2.13 (for hours worked) and Table 2.14 (for jobs).

The first result of interest concerns the speed of adjustment towards the long-run labour input, governed by the estimate labeled $EC_{i,t}$ in the tables. Table 2.12 shows that in the benchmark case (labour input and all industry type) this parameter equals -0.1436, which indicates that about 15 percent of the gap between the targeted (frictionless) labour input and its actual value is closed every period-year, which is in line with previous studies (Burgess and Knetter, 1998). This 15 percent annual adjustment of the gap is fairly stable across industry types (high- or low-NTE) as well as for alternative definitions of labour (see Table 2.13 for hours worked and Table 2.14 for jobs). These results suggest the presence of significant costs of adjusting labour and a very gradual progression, with a half-life between 4 and 5 years, towards the target.

The second group of results of interest taken from Tables 2.12 to 2.14 concerns the influence of the exchange rate. As the tables indicate, the lagged values of the (growth in) exchange rates exert an important influence on the labour input of Canadian manufacturing firms.[32] These results suggest that along the transition towards its long-run target, the labour input of Canadian manufacturing firms is subjected to sizeable fluctuations associated with lagged movements in exchange rates. The numerical estimate suggest that along this path, a 10 percent appreciation of the Canadian currency would cause (ultimately transitory) decreases in the labour input by a factor of between 2 percent and 2.5 percent. Decomposing industries into high- and low-NTE shows that this effect is particularly present for high-NTE industries and not statistically significant for low-NTE ones. It is interesting to note that only the lagged values of Δs_t have a statistically significant impact: exchange rate movements appear to have only a lagged protracted impacts on labour input.

[31] The dynamic adjustment of (2.5) necessitates, by construction, the labour input to be represented by its first lag.

[32] Recall that this effect is separate from the one arising when the *level* of the exchange rate affects the long-run (frictionless) labour input.

Table 2.14 also show that the effect of exchange rate affects both the intensive and the extensive margins: industries tend to decrease the total jobs but also the average number of hours worked for remaining jobs.

Table 2.12: Short-term Dynamics
Labour Input ($\Delta \ln l_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1436***	-0.1527***	-0.1363***
$\Delta \ln l_{i,t-1}$	0.1120***	0.1124**	0.1306**
$\Delta \ln w_{i,t}$	-0.0466	-0.0684	0.0278
$\Delta \ln p^K_{i,t}$	0.0773***	0.0813***	0.0649***
$\Delta \ln p^{II}_{i,t}$	0.0751	0.1070	-0.0267
$\Delta \ln a_{i,t}$	-0.8597***	-0.4225***	-1.7385***
$\Delta \ln s_t$	0.0328	0.0883**	-0.0715
$\Delta \ln s_{t-1}$	-0.2315***	-0.3000***	-0.0654
$\Delta \ln y^{all}_t$	1.2277***	1.3839***	0.7615***

Note: Estimates of the short-term relationship (2.5) in the text. The three columns depict estimates obtained for all, high- and low-NTE industries. The symbols *,** and *** indicate statistical significance of the coefficient at the 10%, 5% and 1% level, respectively. Estimated coefficients and statistical inference for all variables are mean-group estimates.

Third, the tables reveal that multifactor productivity $a_{i,t}$ also affects the dynamic adjustment trajectory. Specifically, Tables 2.12 to 2.14 reveal that a 1 percent increase in productivity reduces labour by close to 1 percent (0.86) for the measures of labour and hours worked (Tables 2.12 and 2.13) but less for jobs (Table 2.14). Recall that multifactor productivity was found to have a positive but not statistically significant influence on the long-run labour input. Its impact on the short-term one may suggest institutional aspects that make it hard for firms to quickly expand production when productivity increases and lead them to service the same markets with a reduced labour input. Finally, Tables 2.12 to 2.14 show that world output also affects importantly the dynamic adjustment towards the long-run equilibrium, in addition to the impact it had on the long-run level. The tables reveal that this impact is large, more than one for one, and is especially important for high-NTE industries.

Table 2.13: Short-term Dynamics

Hours Worked ($\Delta \ln h_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1276***	-0.1349***	-0.1338***
$\Delta \ln l_{i,t-1}$	0.1160***	0.1219***	0.1304**
$\Delta \ln w_{i,t}$	-0.0576	-0.0743	0.0213
$\Delta \ln p^K_{i,t}$	0.0735***	0.0810***	0.0553***
$\Delta \ln p^{II}_{i,t}$	0.0597	0.0926	-0.0582
$\Delta \ln a_{i,t}$	-0.8554***	-0.4308***	-1.6960***
$\Delta \ln s_t$	0.0219	0.0643	-0.0633
$\Delta \ln s_{t-1}$	-0.2445***	-0.3105***	-0.0791
$\Delta \ln y^{all}_t$	1.2606***	1.4110***	0.7954***

Note: See note of Table 2.12.

Figure 2.2 provides a useful way to visualize the value-added of the dynamic adjustment component of our estimation strategy. Panel (a) of the figure plots observed values for labour against the value predicted by the long-run relation (2.3) only, without allowing for the dynamic adjustment (2.5), while Panel (b) depicts the observed and predicted series according to the full model (2.5), which accounts for both the estimated long-run relation and the dynamic adjustment towards that long-run relation. The figure shows that the full model, which includes the dynamic adjustment components, is better able to fit both the levels and the timing of the swings in labour input over our sample.[33]

[33]The figure plots the observed and predicted values of the labour input in the all-industries case. Predicted labour is generated recursively by the model for each year, with the initial year in our sample (1961) serving as the initial condition. This recursive method implies that the actual lagged labour input is never used to generate the predictions. The root mean square error is reduced by close to 28 percent by using the full model.

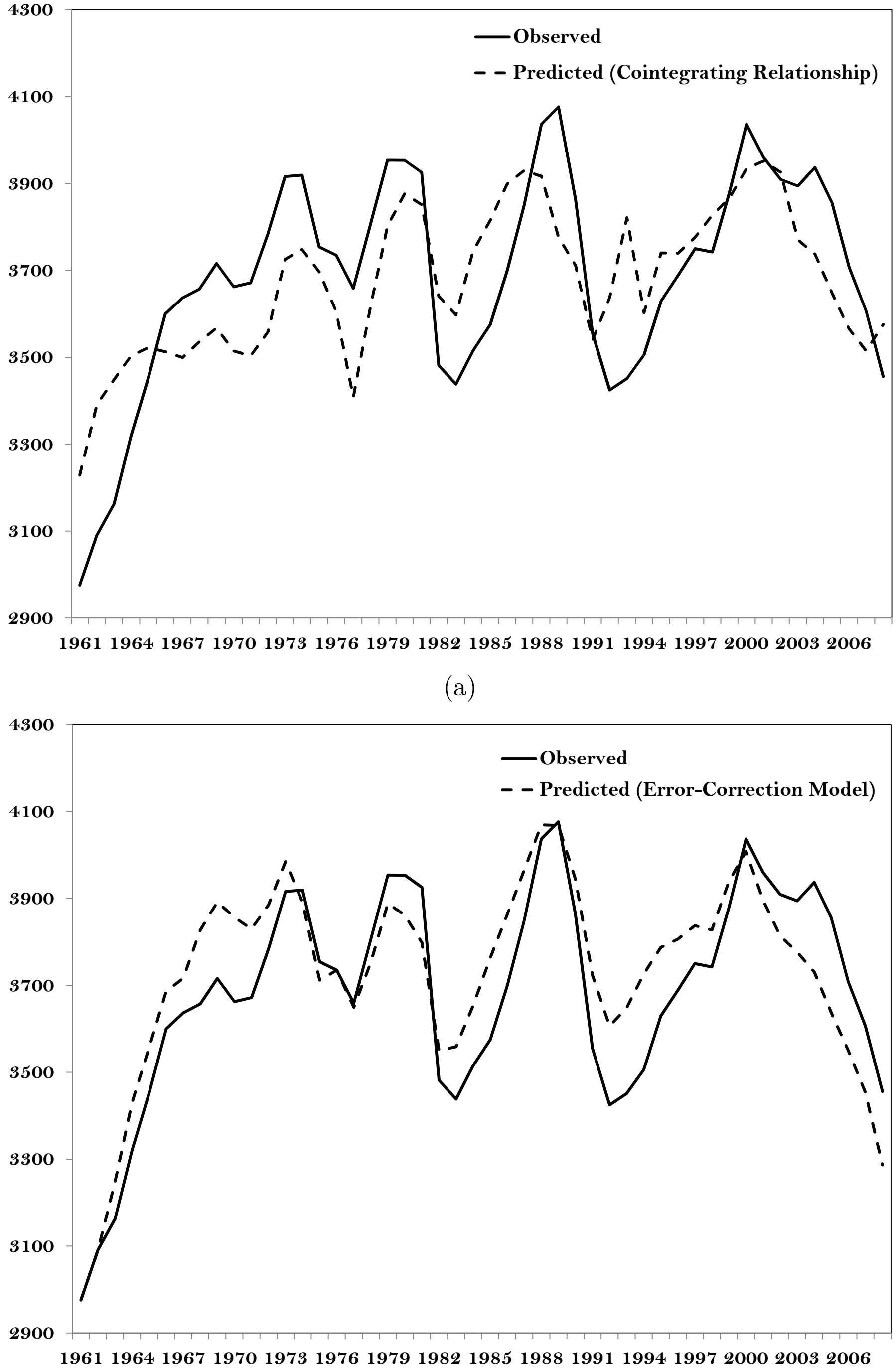
Table 2.14: Short-term Dynamics
Jobs ($\Delta \ln j_{i,t}$)

Variables	Industries		
	All	High NTE	Low NTE
$EC_{i,t}$	-0.1265***	-0.1241***	-0.1664***
$\Delta \ln l_{i,t-1}$	0.1949***	0.2013***	0.2048***
$\Delta \ln w_{i,t}$	-0.0945**	-0.1448***	0.0522
$\Delta \ln p^K_{i,t}$	0.0503***	0.0538***	0.0399**
$\Delta \ln p^{II}_{i,t}$	0.0635	0.1086	-0.0735
$\Delta \ln a_{i,t}$	-0.5864***	-0.1958**	-1.3108***
$\Delta \ln s_t$	0.0123	0.0603	-0.0817
$\Delta \ln s_{t-1}$	-0.2096***	-0.2627***	-0.0788
$\Delta \ln y^{all}_t$	1.1357***	1.3098***	0.6142***

Note: See note of Table 2.12.

2.6 Conclusion

We present evidence that the cycles of boom and bust experienced in the labour market of Canada's manufacturing industries over the last decades is strongly connected to fluctuations in the exchange rate of the Canadian dollar. Our econometric strategy employs panel data estimation techniques and carefully controls for the unit roots, cointegration and cross-sectional dependence found in the data. Our results suggest that a 10 percent appreciation of the Canadian dollar can decrease hours worked and jobs by around 3 percent and that this effect occurs relatively slowly, with about 13 percent of the gap between actual and targeted labour being closed every year. We also find that the GDPs of Canada's trading partners have important effects on Canadian manufacturing jobs. These results are stronger in industries with above-average net trade exposure and we finds that the enactment of two major trade agreements in 1989 and 1994 had sizeable negative impacts on the number of hours worked and jobs in Canadian manufacturing industries. These results are timely, as the recent depreciation of the Canadian dollar has revived interest about the future evolution of Canada's manufacturing industries.



(a)

(b)

Figure 2.2: Hours Worked Dynamic In-Sample Predictions for (a) Cointegrating (Long-run) Relationship only and for (b) Error-correction Model

Chapter 3

Housing Market Dynamics and Macroprudential Policy

with Ian Christensen and Césaire A. Meh

3.1 Introduction

The correlation between consumption expenditures and house prices over the business cycles is well documented in macroeconomics studies. Indeed, time-series estimates for a variety of countries - including Canada - have shown that the two variables tend to move together. Understanding the dynamics between house prices and households debt build ups is particularly important for policy makers, as it has been established that housing busts preceded by large household debt increases tend to result in deeper recessions (IMF, 2012). One of the most well-known cases is the crisis that occurred in the late 2000s in the United States: the elevated level of household debt, combined with a decrease in mortgage underwriting standards and exuberant expectations regarding future house price gains, exposed the U.S. financial system to a sudden reversal in housing markets. Once the exuberance in housing waned, the decline in house prices and the resulting increase in mortgage defaults put in danger the balance sheets of financial institutions that were directly or indirectly exposed to the housing sector. The economic fallout resulting from the financial crisis was also more painful and prolonged relative to a standard recession, as households and financial institutions engaged in a long deleveraging process following the crisis. During the same period, Canada also experienced a significant increase in house prices, residential mortgages[1] and consumer credit. House prices doubled and ratios of house prices to income and house prices to rent increased sharply (IMF, 2013). Mortgage credit expanded by almost 9 percent per year on average between 2000 and 2008, while households debt as a share of disposable income rose from about 100 percent in 2000 to 165 percent in 2013. As a result, mortgage and consumer loans secured by real estate (mostly HELOCS) are estimated to account for 80 percent of household debt and to represent the single largest exposure for Canadian banks with about 35 percent of their assets. This brings many analysts to believe that Canada's housing boom is the most significant risk for its financial stability.

The goal of this chapter is twofold. We first investigate the importance of the link between rising house prices and higher consumption expenditures that operates through improvements in household debt capacity. Specifically, we try to establish whether this link is important and whether it is more demand- or supply-driven. We also follow the *news shocks* literature to determine if a housing-market boom-bust can arise endogenously following unrealized expectations of a rise in housing demand. To this end, we construct a New Keynesian model in which a fraction of households borrow against the value of their houses. We estimate the model with Canadian data using Bayesian methods. We then assess the model's ability to capture key features of consumption and house price data. Secondly, we compare the effectiveness of introducing a countercyclical loan-to-value (LTV) ratio in reducing household indebtedness and housing price fluctuations to a monetary policy rule augmented with house price inflation.

This study is related to the business cycle literature on the role of collateral constraints in the transmission of shocks. A key feature of the existing models is that collateral effects are a propagation mechanism rather than a source of macroeconomic fluctuations. For instance, Iacoviello and Neri (2010) estimates a New Keynesian model and study the sources and consequences of fluctuations in the U.S. housing market. Their results suggest that

[1] Including Home Equity Lines of Credit, or HELOCs.

slow technological progress in the housing sector explains the upward trend in real housing prices over the last 40 years and that the housing market spillovers are non-negligible, concentrated on consumption rather than business investment, and have become more important over time. Lambertini et al. (2010b) analyze housing market boom-bust cycles driven by changes in households' expectations and find that, in the presence of nominal rigidities on prices and wages, expectations on both the conduct of monetary policy and future productivity can generate housing market boom-bust cycles in accordance with the empirical findings. Finally, Gelain et al. (2013) find that the introduction of a simple moving-average forecast rules, a deviation from the rational expectations hypothesis, for a subset of agents and can significantly magnify the volatility and persistence of house prices and household debt relative to an otherwise similar model with fully rational expectations.

Our model shares many features with Iacoviello and Neri (2010). At the core of the model is the borrowers-lenders set-up developed by Kiyotaki and Moore (1997). There are two types of households differentiated by the degree to which they discount the future. In equilibrium, one type of household is a lender and the other type a borrower. Borrowers face a collateral constraint that limits their ability to borrow to a fraction of the value of their housing assets. Rising house values can therefore improve the debt capacity of borrowers, allowing them to increase consumption. Households buy and sell housing in a centralized market.

Since our goal is to quantify the links between consumption and house prices in Canada, we estimate the model with Canadian data using Bayesian methods. To this end we extend the model of Iacoviello and Neri (2010) along two important dimensions. First, we introduce multi-period fixed-rate mortgage loan. On the theoretical ground, standard dynamic stochastic general equilibrium (DSGE) models with housing like Iacoviello and Neri (2010) and many others typically abstract from it by assuming one-period variable-rate loans. Considering that the median length of a mortgage contract in Canada is 5 years and the vast majority are at fixed-rate, this feature is potentially crucial to replicate business cycles facts and to study the (in)effectiveness of macroprudential policies.[2] Secondly,

[2]This feature is introduced exogenously. Future research would study why this framework arise en-

we calibrated the share of patient and impatient households to reflects characteristics of wealth and income distribution data. By using a calibration that underestimates the share of impatient households, the mortgage debt-to-GDP ratio is also underestimated, and thus results in the underestimation of the amplifier effects of macroprudential policies changes on the broader economy.

We find statistical evidence suggesting an important collateral links between the housing market and the rest of the economy, and this link is mainly driven by demand factors. We also find that the introduction of news shocks can generate a housing market boom-bust cycle, the bust following an unrealized expectations on housing demand.

The second objective of the chapter is related to macroprudential policy, more specifically LTV ratio. Introduced to mitigate risk build ups in the real estate market, LTV ratio impose a cap on the size of a mortgage loan relative to the value of a property, thereby requiring a minimum down payment.[3] It is believed that LTV ratio can contain boom-bust cycles by controlling both credit and expectations channels and strengthening financial institutions' resilience: lowering limits on LTV can tighten liquidity constraints of targeted borrowers and thus limits housing demand in targeted segments of the real estate market (and vice versa in the downturn). This has for effect of altering market expectations and speculative incentives that play a key role in bubble dynamics.

Our work is related to a few strands in the literature. First, there are papers that considers either or both the effects of monetary policy of monetary policy and changes in regulatory LTV in a DSGE framework similar to Iacoviello (2005) and Iacoviello and Neri (2010). A non-exhaustive list includes Christensen et al. (2009), Kannan et al. (2012), Justiniano et al. (2013), Lambertini et al. (2013), Gelain et al. (2013) and Gelain et al. (2014). Lambertini et al. (2013) studies the potential gains of monetary and macro-prudential policies that lean against house-price and credit cycles and find that, when the implementation of both interest-rate and LTV policies is allowed, heterogeneity in the welfare implications is key in determining the optimal use of policy instruments. Finally, Gelain et al. (2014)

dogenously within the mortgage market.

[3] See Appendix 3.4 for the recent history of LTV policies in Canada.

find that monetary policy is less effective when contracts are multi-period, but only under fixed rate mortgages or when borrowers cannot be forced to accelerate repayment of their loans.

Our study suggests that higher loan-to-value ratios can amplify housing-market boom-bust cycles by encouraging speculative housing investments by credit-constrained borrowers, but the amplification effect is mainly concentrated via the collateral constraints. However, our study suggests that, in line with preceding dynamic equilibrium models with credit-constrained borrowers considered by Iacoviello (2005) and Kiyotaki et al. (2010), the loan-to-value ratio does not significantly alter aggregate house-price dynamics.

This remainder of the chapter is organized as follows. Section 3.2 presents the theoretical model. Section 3.3 describes the calibration, discusses estimation issues and our econometric strategy and introduces the data employed. Section 3.4 discusses the estimation results and the overall performance of the model to describe business cycle characteristics, while Section 3.5 reports the effect of the introduction of a countercyclical LTV ratio. Section 3.6 concludes. A detailed description of all data used is presented in the appendices.

3.2 A Model of Irreversible Housing Investment

We start from a standard New Keynesian set-up, extended to incorporate irreversible housing investment and credit frictions, as in Iacoviello (2005) and Iacoviello and Neri (2010). Our economic environment features heterogeneity among economic agents. We consider an economy populated by two types of households, designated as borrowers and lenders. Credit flows are generated by assuming *ex-ante* heterogeneity in agents' subjective discount factors. Impatient consumers (borrowers) differ from patient consumers (lenders) in that they discount the future at a faster rate. Hence, in equilibrium, patient agents are net lenders while impatient agents are net borrowers. To prevent borrowing from growing without limit, we assume that borrowers face credit constraints tied to the current value of their collateral. We depart from the usual set-up of one-period loans with variable interest rates by allowing for multi-period loans with fixed interest rates (Gelain et al., 2014; Alpanda et al., 2014; Alpanda and Zubairy, 2014).

There are two sectors of production in the economy: consumption and housing. Each variety of consumption goods is produced by a single firm in a monopolistic competitive environment and their prices are set in a staggered fashion *à la* Calvo (1983). A representative firm produces houses in a perfectly competitive environment. Households supply differentiated labour in a monopolistic competitive environment - their wages being set in a staggered fashion *à la* Calvo (1983) - and buy goods, deriving their utility from consumption goods and from services provided by their housing stock. Credit flows are generated via perfectly competitive financial intermediaries, which accept deposits from patient households to lend to impatient households. Finally, a central bank conducts monetary policy according to a Taylor-type rule.

3.2.1 Households

Households $i \in \{P, I\}$, respectively patient and impatient households, derive in period t strictly increasing utility from consumption goods $c_{i,t}$ and from services provided by their housing stock $h_{i,t}$. They supply labour and derive a strictly decreasing utility from hours worked in the consumption sector $n^c_{i,t}$, and hours worked in the housing sector $n^h_{i,t}$. They maximize their expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_i^t \epsilon_t^b U\left(c_{i,t}, h_{i,t}, n^c_{i,t}, n^h_{i,t}\right), \tag{3.1}$$

where E_0 is the mathematical expectation operator given the time 0 information set, $\beta_i \in (0,1)$ is the subjective discount factor and ϵ_t^b represents an exogenous process on discount rates that affects the intertemporal substitution of households.[4] The functional form of U is

$$U(\bullet) = \log(x_{i,t}) - \frac{\epsilon_t^n}{1+\eta_i}\left(\left(n^c_{i,t}\right)^{\frac{\theta_i^n+1}{\theta_i^n}} + \left(n^h_{i,t}\right)^{\frac{\theta_i^n+1}{\theta_i^n}}\right)^{\frac{\theta_i^n(1+\eta_i)}{\theta_i^n+1}},$$

[4]The process ϵ^b has been identified to be an important driver of consumption fluctuations in recent DSGE literature (Smets and Wouters, 2007; Justiniano et al., 2010).

where ϵ_t^n is an exogenous process on labour supplies, and θ_i^n and η_i are, respectively, the strictly positive intratemporal elasticity of substitution between sectoral labour supplies and the inverse of Frish elasticity of substitution. This specification of disutility of labour follows Horvath (2000). When $\theta_i^n \to \infty$, hours worked in each sector tends to be perfect substitutes as agents devote all of their time to the sector paying the highest wage and all sectors pay the same hourly wage at the margin. The final good $x_{i,t}$ is defined as a CES composite of consumption (non-durable) goods $c_{i,t}$ and housing stock $h_{i,t}$

$$x_{i,t} = \left[\left(1 - \epsilon_t^h\right)^{\frac{1}{\theta_i^x}} c_{i,t}^{\frac{\theta_i^x - 1}{\theta_i^x}} + \left(\epsilon_t^h\right)^{\frac{1}{\theta_i^x}} h_{i,t}^{\frac{\theta_i^x - 1}{\theta_i^x}} \right]^{\frac{\theta_i^x}{\theta_i^x - 1}}, \tag{3.2}$$

where ϵ_t^h is an exogenous process on the preference for services provided by the housing stock (i.e. housing demand shock) and θ_i^x is the strictly positive intratemporal elasticity of substitution between consumption goods and the services provided by the housing stock. When $\theta_i^x \to \infty$, both goods tend to be perfect substitutes whereas they tend to be perfect complements when $\theta_i^x \to 0$.

Labour Labour decisions are made by a central authority within the households, which supplies, in a monopolistic competitive environment, differentiated labour $n_{i,l,t}^j$ in a continuum of labour markets $l \in [0,1]$ in sector $j \in \{c, h\}$.[5] Both sectors are, in terms of notation, the same. Given the wage charged in each labour market l of sector j, the central authority supplies labour to satisfy the demand given by

$$n_{i,l,t}^j = \left(\frac{w_{i,l,t}^j}{w_{i,t}^j} \right)^{-\theta^{n^j}} n_{i,t}^{j,d}, \tag{3.3}$$

where $w_{i,l,t}^j = \frac{W_{i,l,t}^j}{P_t^c}$ and $w_{i,t}^j = \frac{W_{i,t}^j}{P_t^c}$ are the real wages. $W_{i,l,t}^j$ denotes the nominal wage charged by the central authority in the labour market l in sector j for agents of type i,

[5]By assuming that all households will act as a representative household, this setup avoids the need to assume separability of preferences and the existence of insurance for labour market. This feature is already reflected in the notation since there are no subscript for the continuum of households of each type i.

$W_{i,t}^{j}$ is the nominal wage index, $n_{i,t}^{j,d}$ is a measure of aggregate labour demand by firms and θ^{n^j} is the wage-elasticity of demand.[6] In each labour market, the central authority takes $W_{i,t}^{j}$ and $n_{i,t}^{j,d}$ as given. In addition, the total numbers of hours allocated to the different labour markets must satisfy the resource constraint in each sector

$$n_{i,t}^{j} = \int_0^1 \left(n_{i,l,t}^{j}\right) dl. \tag{3.4}$$

Combining this restriction with equation (3.3) yields the aggregated labour supply in each sector j:

$$n_{i,t}^{j} = n_{i,t}^{j,d} \int_0^1 \left(\frac{w_{i,l,t}^{j}}{w_{i,t}^{j}}\right)^{-\theta^{n^j}} dl. \tag{3.5}$$

Patient (Lenders) Patient households ($i = P$) have a higher propensity to save (i.e. $\beta_P > \beta_I$). In equilibrium, they supply loans to impatient households ($i = I$) via their deposit d_t at financial intermediaries and accumulate housing and capital stock. Since lenders are the owners of the banks and firms in both sectors, they receive dividends f_t^c, f_t^h and f_t^{fi} from the consumption and housing sectors and from financial intermediaries, respectively. They maximize their expected lifetime utility (3.1) subject to their budget constraint in real terms (in units of consumption goods)

$$\begin{aligned} c_{P,t} + q_t^h i_{P,t}^h + \sum_{j\in\{c,h\}} q_t^{k^j} i_t^{k^j} + q_t^l l_t + b_{P,t} + d_t = \sum_{j\in\{c,h\}} r_t^{k^j} u_t^{k^j} k_{t-1}^{j} + \left(q_t^l + r_t^l\right) l_{t-1} + \\ \sum_{j\in\{c,h\}} n_{P,t}^{j,d} \int_0^1 w_{P,l,t}^{j} \left(\frac{w_{P,l,t}^{j}}{w_{P,t}^{j}}\right)^{-\theta^{n^j}} dl + \frac{R_{t-1} b_{P,t-1}}{\pi_t^c} + \sum_{j\in\{c,h,fi\}} f_t^j + \\ \frac{1}{\phi^m} \sum_{s=1}^{\phi^m} \frac{d_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} + \sum_{s=1}^{\phi^m} \left(R_{t-s}^d - 1\right) \left(\frac{\phi^m - s + 1}{\phi^m}\right) \frac{d_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c}, \end{aligned} \tag{3.6}$$

the law of motion for capital in sector j

$$k_t^j = \left(1 - \delta_t^{k^j}\right) k_{t-1}^j + z_t^{i^k} i_t^{k^j} \left[1 - \frac{\phi^{k^j}}{2} \left(\frac{i_t^{k^j}}{i_{t-1}^{k^j}} - 1\right)^2\right], \tag{3.7}$$

[6]The formal derivation of the labour demand function is presented in the Section 3.2.2.

and the law of motion for housing stock

$$h_{P,t} = \left(1 - \delta^h\right) h_{P,t-1} + i^h_{P,t}, \tag{3.8}$$

where q^h_t is the real price of housing, $i^h_{P,t}$ is the investment in housing stock and δ^h is its fixed depreciation rate. With $j \in \{c, h\}$, k^j_t is the stock of capital specific to sector j, $i^{k^j}_t$ its investment level, $r^{k^j}_t$ its real rental rate, $u^{k^j}_t$ its variable capacity utilization rate and $\delta^{k^j}_t$ its variable depreciation rate. Lenders invest $i^{k^j}_t$ in k^j with $q^{k^j}_t$ being the real price of investment in sector j. Lenders owns all the land stock l_t, which has a real price q^l_t and a real rental rate r^l_t. The stock of land is exogenous and evolves with an autoregressive process. π^c_t is the gross inflation rate in the consumption sector and R_t is the gross nominal interest rate on risk-less one-period bonds $b_{P,t-1}$. Lenders' savings take the form of a long-term deposit at the financial intermediaries at the constant interest rate R^d_t. The deposit length is ϕ^m periods and, at each period, the lenders receive a share $\frac{1}{\phi^m}$ of the principal as a reimbursement of the deposit and a fixed return on investment $\left(R^d_t - 1\right)$ on the principal not reimbursed at the last period. Finally, ϕ^{k^c} and ϕ^{k^h} are the adjustment cost parameters. The technology transforming investment goods into capital goods is subject to a transitory exogenous process denoted z^{ik}_t.[7]

Lenders can control the intensity at which the capital stock is utilized. The effective amount of capital services supplied to firms in the consumption and housing sectors in period t are given by $u^{k^c}_t k^c_{t-1}$ and $u^{k^h}_t k^h_{t-1}$, respectively. We assume that increasing the intensity of capital utilization entails a cost in the form of a faster rate of depreciation. Specifically, we assume that depreciation rates $\delta^{k^j}_t$ are an increasing and convex function of the rate of capacity utilization

$$\delta^{k^j}_t = \delta^{k^j}_0 + \delta^{k^j}_1 \left(u^{k^j}_t - 1\right) + \frac{\delta^{k^j}_2}{2} \left(u^{k^j}_t - 1\right)^2, \tag{3.9}$$

with $\delta^{k^j}_0, \delta^{k^j}_1, \delta^{k^j}_2 > 0$ (as in Schmitt-Grohe and Uribe (2012)).

[7]This type of process has been identified by Justiniano et al. (2010) as an important source of aggregate economic fluctuations.

Substituting (3.7) to (3.9) into (3.6), the first-order necessary conditions for $c_{P,t}$, $h_{P,t}$, $n^c_{P,t}$, $n^h_{P,t}$, k^c_t, k^h_t, l_t, $u^{k^c}_t$, $u^{k^h}_t$, $i^{k^c}_t$, $i^{k^h}_t$, $b_{P,t}$ and d_t are, respectively[8],

$$\lambda^c_{P,t} = \frac{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} c_{P,t}^{\frac{-1}{\theta^x_P}}}{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} c_{P,t}^{\frac{\theta^x_P-1}{\theta^x_P}} + \left(\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} h_{P,t}^{\frac{\theta^x_P-1}{\theta^x_P}}}, \tag{3.10}$$

$$\lambda^c_{P,t} q^h_t - \beta_P \left(1-\delta^h\right) E_t\left[\lambda^c_{P,t+1} q^h_{t+1}\right] = \frac{\left(\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} h_{P,t}^{\frac{-1}{\theta^x_P}}}{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} c_{P,t}^{\frac{\theta^x_P-1}{\theta^x_P}} + \left(\epsilon^h_t\right)^{\frac{1}{\theta^x_P}} h_{P,t}^{\frac{\theta^x_P-1}{\theta^x_P}}}, \tag{3.11}$$

$$\epsilon^b_t \epsilon^n_t \left(\left(n^c_{P,t}\right)^{\frac{\theta^n_P+1}{\theta^n_P}} + \left(n^h_{P,t}\right)^{\frac{\theta^n_P+1}{\theta^n_P}}\right)^{\frac{\theta^n_P \eta_P - 1}{\theta^n_P+1}} \left(n^c_{P,t}\right)^{\frac{1}{\theta^n_P}} = \frac{\lambda^c_{P,t} w^c_{P,t}}{\lambda^{n^c}_{P,t}}, \tag{3.12}$$

$$\epsilon^b_t \epsilon^n_t \left(\left(n^c_{P,t}\right)^{\frac{\theta^n_P+1}{\theta^n_P}} + \left(n^h_{P,t}\right)^{\frac{\theta^n_P+1}{\theta^n_P}}\right)^{\frac{\theta^n_P \eta_P - 1}{\theta^n_P+1}} \left(n^h_{P,t}\right)^{\frac{1}{\theta^n_P}} = \frac{\lambda^c_{P,t} w^h_{P,t}}{\lambda^{n^h}_{P,t}}, \tag{3.13}$$

$$\lambda^c_{P,t} q^{k^c}_t = \beta_P E_t\left[\lambda^c_{P,t+1}\left(u^{k^c}_{t+1} r^{k^c}_{t+1} + q^{k^c}_{t+1}\left(1-\delta^{k^c}_{t+1}\right)\right)\right], \tag{3.14}$$

$$\lambda^c_{P,t} q^{k^h}_t = \beta_P E_t\left[\lambda^c_{P,t+1}\left(u^{k^h}_{t+1} r^{k^h}_{t+1} + q^{k^h}_{t+1}\left(1-\delta^{k^h}_{t+1}\right)\right)\right], \tag{3.15}$$

$$\lambda^c_{P,t} q^l_t = \beta_P E_t\left[\lambda^c_{P,t+1}\left(q^l_{t+1} + r^l_{t+1}\right)\right], \tag{3.16}$$

$$r^{k^c}_t = q^{k^c}_t\left[\delta^{k^c}_1 + \delta^{k^c}_2\left(u^{k^c}_t - 1\right)\right], \tag{3.17}$$

$$r^{k^h}_t = q^{k^h}_t\left[\delta^{k^h}_1 + \delta^{k^h}_2\left(u^{k^h}_t - 1\right)\right], \tag{3.18}$$

$$\begin{aligned}\lambda^c_{P,t}\left(1 - q^{k^c}_t z^{i^k}_t\left(1 - \frac{\phi^{k^c}}{2}\left(\frac{i^{k^c}_t}{i^{k^c}_{t-1}} - 1\right)^2 - \phi^{k^c}\left(\frac{i^{k^c}_t}{i^{k^c}_{t-1}} - 1\right)^2 \frac{i^{k^c}_t}{i^{k^c}_{t-1}}\right)\right) = \\ \beta_P E_t\left[\lambda^c_{P,t+1} q^{k^c}_{t+1} z^{i^k}_{t+1} \frac{\phi^{k^c}}{2}\left(\frac{i^{k^c}_{t+1}}{i^{k^c}_t} - 1\right)^2 \left(\frac{i^{k^c}_{t+1}}{i^{k^c}_t}\right)^2\right],\end{aligned} \tag{3.19}$$

[8]See Appendix 3.3 for the Lagrangian.

$$\lambda^c_{P,t}\left(1-q^{k^h}_t z^{i^k}_t\left(1-\frac{\phi^{k^h}}{2}\left(\frac{i^{k^h}_t}{i^{k^h}_{t-1}}-1\right)^2-\phi^{k^h}\left(\frac{i^{k^h}_t}{i^{k^h}_{t-1}}-1\right)^2\frac{i^{k^h}_t}{i^{k^h}_{t-1}}\right)\right)=$$
$$\beta_P E_t\left[\lambda^c_{P,t+1}q^{k^h}_{t+1}z^{i^k}_{t+1}\frac{\phi^{k^h}}{2}\left(\frac{i^{k^h}_{t+1}}{i^{k^h}_t}-1\right)^2\left(\frac{i^{k^h}_{t+1}}{i^{k^h}_t}\right)^2\right], \quad (3.20)$$

$$\lambda^c_{P,t}=\beta_P R_t E_t\left[\frac{\lambda^c_{P,t+1}}{\pi^c_{t+1}}\right], \quad (3.21)$$

and

$$\lambda^c_{P,t}=\sum_{s=1}^{\phi^m}\beta^s_P E_t\left[\frac{\lambda^c_{P,t+s}}{\prod_{v=1}^s \pi^c_{t+v}}\left(\tfrac{1}{\phi^m}+\left(R^d_t-1\right)\left(\tfrac{\phi^m-s+1}{\phi^m}\right)\right)\right], \quad (3.22)$$

where $\lambda^c_{P,t}$ is the Lagrange multiplier on budget constraint (3.6), $\frac{\lambda^c_{P,t}w^j_{P,t}}{\lambda^{n^j}_{P,t}}$ and $\lambda^c_{P,t}q^{k^j}_t$ are the Lagrange multipliers on labour supply constraints (3.5) and the law of motion of capital (3.7), respectively. Equation (3.10) describes the marginal utility of current consumption of non-durable goods. Equation (3.11) requires that households equate the marginal utility of current consumption goods to the marginal utility increase of housing stock services, the latter being composed of two parts: (i) the direct utility gain of an additional unit of housing, and (ii) the expected utility stemming from the consumption of the resale value of housing purchased in previous periods. Equations (3.12) and (3.13) link real wages in both sectors to households' marginal rate of substitution between consumption goods and leisure. In equilibrium, real wages in the consumption and housing sectors are equal. Equations (3.14) and (3.15) requires that households equate their marginal utility of current consumption goods to the marginal utility increase of an additional unit of capital, which includes two parts: (i) the rental rate of capital, and (ii) the expected utility stemming from the consumption of the resale value of undepreciated capital purchased in previous periods. Equations (3.17) and (3.18) link the variable capacity utilization rate to the rental rate of capital. Equations (3.19) and (3.20) require that households equate the investment cost, in terms of the foregone marginal utility of consumption goods, to the expected value of the rebate in adjustment cost in the following period. Equation (3.21) is the typical Euler condition that equates the cost of sacrificing one unit of consumption goods to the benefit of investing in the bond market.[9] Finally, equation 3.22 equates the cost of sacrificing one unit of consumption goods to the benefit of making deposits generating a flow of revenues for ϕ^m periods.

Impatient (Borrowers) The impatient households ($i = I$) do not accumulate physical capital nor hold any equity, and have access to multi-period fixed-rate mortgage loans with fixed (linear) principal payments, so that in each period a borrowers have to pay interest on the outstanding debt and repay the amount of principal due. They maximize their expected lifetime utility (3.1) subject to a budget constraint

$$c_{I,t} + q_t^h i_{I,t}^h + b_{I,t} + \frac{1}{\phi^m} \sum_{s=1}^{\phi^m} \frac{m_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} + \sum_{s=1}^{\phi^m} \left(R_{t-s}^m - 1 \right) \left(\frac{\phi^m - s + 1}{\phi^m} \right) \frac{m_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} = \sum_{j \in \{c,h\}} n_{I,t}^{j,d} \int_0^1 w_{I,l,t}^j \left(\frac{w_{I,l,t}^j}{w_{I,t}^j} \right)^{-\theta^{n^j}} dl + \frac{R_{t-1} b_{I,t-1}}{\pi_t^c} + m_t, \quad (3.23)$$

to their law of motion for housing stock

$$h_{I,t} = \left(1 - \delta^h\right) h_{I,t-1} + i_{I,t}^h, \quad (3.24)$$

and a borrowing constraint. Private borrowing is subject to an endogenous limit. At any time t, borrowers agree to borrow no more than a share ω (Kiyotaki and Moore, 1997; Monacelli, 2009) of the current value of their housing stock:

$$M_t \geq -\omega q_t^h h_{i,t}, \quad (3.25)$$

where

$$M_t = \sum_{s=0}^{\phi^m} \left(\frac{\phi^m - s + 1}{\phi^m} \right) \frac{m_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c}, \quad (3.26)$$

[9] Since lenders own all firms and financial intermediairies, it also determines the pricing kernel of the economy.

is the total mortgage debt.[10] The model reflects the fact that mortgage debt is reoptimized only for the share of contracts that reach their end and have to refinance.[11]

Substituting (3.24) into (3.23), the first-order necessary conditions for $c_{I,t}$, $h_{I,t}$, $n^c_{I,t}$, $n^h_{I,t}$, $b_{I,t}$ and m_t are, respectively[12],

$$\lambda^c_{I,t} = \frac{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} c_{I,t}^{\frac{-1}{\theta^x_I}}}{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} c_{I,t}^{\frac{\theta^x_I-1}{\theta^x_I}} + \left(\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} h_{I,t}^{\frac{\theta^x_I-1}{\theta^x_I}}}, \tag{3.27}$$

$$\lambda^c_{I,t} q^h_t - \beta_I \left(1-\delta^h\right) E_t\left[\lambda^c_{I,t+1} q^h_{t+1}\right] = \\ \frac{\left(\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} h_{I,t}^{\frac{-1}{\theta^x_I}}}{\left(1-\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} c_{I,t}^{\frac{\theta^x_I-1}{\theta^x_I}} + \left(\epsilon^h_t\right)^{\frac{1}{\theta^x_I}} h_{I,t}^{\frac{\theta^x_I-1}{\theta^x_I}}} + \lambda^c_{I,t}\lambda^b_t \omega q^h_t, \tag{3.28}$$

$$\epsilon^b_t \epsilon^n_t \left(\left(n^c_{I,t}\right)^{\frac{\theta^n_I+1}{\theta^n_I}} + \left(n^h_{I,t}\right)^{\frac{\theta^n_I+1}{\theta^n_I}}\right)^{\frac{\theta^n_I \eta_I - 1}{\theta^n_I+1}} \left(n^c_{I,t}\right)^{\frac{1}{\theta^n_I}} = \frac{\lambda^c_{I,t} w^c_{I,t}}{\lambda^{n^c}_{I,t}}, \tag{3.29}$$

$$\epsilon^b_t \epsilon^n_t \left(\left(n^c_{I,t}\right)^{\frac{\theta^n_I+1}{\theta^n_I}} + \left(n^h_{I,t}\right)^{\frac{\theta^n_I+1}{\theta^n_I}}\right)^{\frac{\theta^n_I \eta_I - 1}{\theta^n_I+1}} \left(n^h_{I,t}\right)^{\frac{1}{\theta^n_I}} = \frac{\lambda^c_{I,t} w^h_{I,t}}{\lambda^{n^h}_{I,t}}, \tag{3.30}$$

$$\lambda^c_{I,t} = \beta_I R_t E_t\left[\frac{\lambda^c_{I,t+1}}{\pi^c_{t+1}}\right], \tag{3.31}$$

and

$$\lambda^c_{I,t}\left(1-\lambda^b_t\right) = \sum_{s=1}^{\phi^m} \beta^s_I E_t\left[\frac{\lambda^c_{I,t+s}}{\prod_{v=1}^{s} \pi^c_{t+v}}\left(\tfrac{1}{\phi^m} + \left(R^m_t - 1\right)\left(\tfrac{\phi^m - s+1}{\phi^m}\right) + \lambda^b_{t+s}\left(\tfrac{\phi^m - s}{\phi^m}\right)\right)\right], \tag{3.32}$$

where $\lambda^c_{I,t}$ is the Lagrange multiplier on budget constraint (3.23), $\frac{\lambda^c_{I,t} w^j_{I,t}}{\lambda^{n^j}_{I,t}}$ and $\lambda^c_{I,t}\lambda^b_{I,t}$ are the Lagrange multipliers on labour supply constraint (3.5) and the borrowing constraint (3.25), respectively. Equations (3.27), (3.29), (3.30) and (3.31) have the same interpretation as for

[10]We use the convention that $m < 0$ is a debt.

[11]In Canada, the median length of mortgage contract is 5 years.

[12]See Appendix 3.3 for the Lagrangian.

the lenders. Finally, equations (3.28) and (3.32) depend on the same two components as the lenders' equations, but also on the marginal utility of relaxing the borrowing constraint.

Wages We introduce wage stickiness in the model by assuming that, in each period, the central authority within the households i cannot set the nominal wage optimally for a share $\xi^{w^j} \in (0,1)$ of labour markets chosen randomly. The first-order necessary conditions for $w^j_{i,l,t}$ is

$$w^j_{i,l,t} = \begin{cases} \tilde{w}^j_{i,t} & \text{if set optimally in } t \\ \frac{w^j_{i,l,t-1}(\pi^c)^{\iota^{w^j}}}{\pi^c_t} & \text{otherwise} \end{cases} . \tag{3.33}$$

In equations (3.33), $\tilde{w}^j_{i,t}$ denotes the real wage prevailing in the $\left(1-\xi^{w^j}\right)$ labour markets in which the central authority can set wages optimally in sector j in period t. Because the labour demand curve faced by the union is identical across all labour markets, and because the cost of supplying labour is the same for all markets, one can assume that wage rate $\tilde{w}^j_{i,t}$ is identical for all industries within a given sector (but not necessarily across sectors). In the ξ^{w^j} labour markets that cannot set wages optimally, the wages are imperfectly indexed at rate ι^{w^j} to the steady-state inflation. The households' first-order necessary condition with respect to the optimally set wage[13] rate in the current period in the production sector j, $\tilde{w}^j_{i,t}$, is

$$E_t \sum_{s=0}^{\infty} \left(\beta_i \xi^{w^j}\right)^s \lambda^c_{i,t+s} n^{j,d}_{i,t+s} \left(\frac{\tilde{w}^j_{i,t}}{w^j_{i,t+s}}\right)^{-\theta^{n^j}} \prod_{k=1}^{s} \left(\frac{(\pi^c)^{\iota^{w^j}}}{\pi^c_{t+k}}\right)^{-\theta^{n^j}} \times$$
$$\left[\frac{\theta^{n^j}-1}{\theta^{n^j}} \tilde{w}^j_{i,t} \prod_{k=1}^{s} \frac{(\pi^c)^{\iota^{w^j}}}{\pi^c_{t+k}} - \frac{w^j_{i,t}}{\lambda^{n^j}_{i,t}}\right] = 0. \tag{3.34}$$

[13]Part of the optimization problem (i.e. the Lagrangian) that is relevant for this purpose can be found in Appendix 3.3.

Using (3.12), (3.13), (3.29) and (3.30) to eliminate $\lambda_{i,t}^{n^j}$ yields

$$E_t \sum_{s=0}^{\infty} \left(\beta_i \xi^{w^j}\right)^s \lambda_{i,t+s}^c n_{i,t+s}^{j,d} \left(\frac{\tilde{w}_{i,t}^j}{w_{i,t+s}^j}\right)^{-\theta^{n^j}} \prod_{k=1}^{s} \left(\frac{\left(\pi^c\right)^{\iota^{w^j}}}{\pi_{t+k}^c}\right)^{-\theta^{n^j}} \left[\frac{\theta^{n^j}-1}{\theta^{n^j}} \tilde{w}_{i,t}^j \prod_{k=1}^{s} \frac{\left(\pi^c\right)^{\iota^{w^j}}}{\pi_{t+k}^c} - \right.$$
$$\left. \frac{1}{\lambda_{i,t+s}^c} \epsilon_{t+s}^b \epsilon_{t+s}^n \left(\left(n_{i,t+s}^c\right)^{\frac{\theta_i^n+1}{\theta_i^n}} + \left(n_{i,t+s}^h\right)^{\frac{\theta_i^n+1}{\theta_i^n}}\right)^{\frac{\theta_i^n \eta_i - 1}{\theta_i^n+1}} \left(n_{i,t+s}^j\right)^{\frac{1}{\theta_i^n}} \right] = 0. \quad (3.35)$$

This equation states that, in labour market in which the wage rate is re-optimized in period t, the real wage is set to equate the expected future average marginal revenue to the average marginal cost of supplying labour. In this equation, $\frac{\theta^{n^j}}{\theta^{n^j}-1}$ represents the markup of wages over the marginal cost of labour that would prevail in the absence of wage stickiness and trend inflation. To write the wage-setting equation in recursive form[14], we need to define intermediate variables $f_{i,t}^{1,j}$ and $f_{i,t}^{2,j}$. This yields

$$\begin{aligned} f_{i,t}^{1,j} =& \frac{\theta^{n^j}-1}{\theta^{n^j}} \left(\tilde{w}_{i,t}^j\right)^{1-\theta^{n^j}} \left(\frac{1}{w_{i,t}^j}\right)^{-\theta^{n^j}} \lambda_{i,t}^c n_{i,t}^{j,d} + \\ & \beta_i \xi^{w^j} E_t \left[\left(\frac{\left(\pi^c\right)^{\iota^{w^j}}}{\pi_{t+1}^c}\right)^{1-\theta^{n^j}} \left(\frac{\tilde{w}_{i,t}^j}{\tilde{w}_{i,t+1}^j}\right)^{1-\theta^{n^j}} f_{i,t+1}^{1,j}\right], \\ f_{i,t}^{2,j} =& \epsilon_t^b \epsilon_t^n \left(\left(n_{i,t}^c\right)^{\frac{\theta_i^n+1}{\theta_i^n}} + \left(n_{i,t}^h\right)^{\frac{\theta_i^n+1}{\theta_i^n}}\right)^{\frac{\theta_i^n \eta_i - 1}{\theta_i^n+1}} \left(n_{i,t}^j\right)^{\frac{1}{\theta_i^n}} \left(\frac{\tilde{w}_{i,t}^j}{w_{i,t}^j}\right)^{-\theta^{n^j}} n_{i,t}^{j,d} + \\ & \beta_i \xi^{w^j} E_t \left[\left(\frac{\left(\pi^c\right)^{\iota^{w^j}}}{\pi_{t+1}^c}\right)^{-\theta^{n^j}} \left(\frac{\tilde{w}_{i,t}^j}{\tilde{w}_{i,t+1}^j}\right)^{-\theta^{n^j}} f_{i,t+1}^{2,j}\right], \\ f_{i,t}^{1,j} =& f_{i,t}^{2,j}. \end{aligned} \quad (3.36)$$

[14]Which is necessary for the representation of the model in state-space form.

3.2.2 Firms

3.2.2.1 Consumption sector

Final good producers In each period t, perfectly competitive final consumption goods producers purchase differentiated intermediate goods $m \in [0,1]$ to assemble final goods y_t^c via the Dixit-Stiglitz aggregator

$$y_t^c = \left[\int_0^1 \left(y_{m,t}^c \right)^{\frac{\theta^c - 1}{\theta^c}} dm \right]^{\frac{\theta^c}{\theta^c - 1}}, \tag{3.37}$$

where parameter θ^c denotes the intratemporal elasticity of substitution across varieties of intermediate differentiated goods[15] and $y_{m,t}^c$ is the demand for goods of variety m.

When maximizing their profits, final goods producers take as given the prices of intermediate goods and the aggregate price index. For any given level of final consumption goods produced, they must solve the expenditure-minimizing problem

$$\min_{\left\{ y_{m,t}^c \right\}} \int_0^1 P_{m,t}^c y_{m,t}^c dm$$

subject to aggregation constraint (3.37), where $P_{m,t}^c$ denotes the price of the intermediate consumption good m at time t. The demand for goods of variety m is then given by

$$y_{m,t}^c = \left(\frac{P_{m,t}^c}{P_t^c} \right)^{-\theta^c} y_t^c, \tag{3.38}$$

where P_t^c is the nominal price index defined as

$$P_t^c = \left[\int_0^1 \left(P_{m,t}^c \right)^{1-\theta^c} dm \right]^{\frac{1}{1-\theta^c}}. \tag{3.39}$$

[15]When $\theta^c \to 0$, intermediate goods are perfect complements, whereas they are perfect substitutes when $\theta^c \to \infty$.

Intermediate good producers Each variety of intermediate goods in the consumption sector is produced by a single firm m evolving in a monopolistic competitive environment. The production function for each of these firm $m \in [0,1]$ is

$$y^c_{m,t} = z^c_t \left(k^c_{m,t}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,m,t}\right)^{\alpha^c} \left(n^{c,d}_{I,m,t}\right)^{1-\alpha^c}\right)^{1-\gamma^c}, \tag{3.40}$$

where $y^c_{m,t}$ is its total production, $n^{c,d}_{P,m,t}$ and $n^{c,d}_{I,m,t}$ are the number of hours of work demanded by the firm for both type of workers, z^c_t is the sector-wide total factor productivity and $k^c_{m,t}$ is the capital stock rented by the firm. Also, γ^c is the capital share of income and α^c is the lenders' share of labour income. The nominal profits (i.e. dividends) of the firm are denoted by

$$F^c_{m,t} = P^c_{m,t} y^c_{m,t} - R^{k^c}_t k^c_{m,t} - W^c_{P,t} n^{c,d}_{P,m,t} - W^c_{I,t} n^{c,d}_{I,m,t}. \tag{3.41}$$

We assume that the firm must satisfy the aggregated demand for good m at posted price

$$y^c_{m,t} = \left(\frac{P^c_{m,t}}{P^c_t}\right)^{-\theta^c} y^c_t. \tag{3.42}$$

The firm's objective is a static problem of profit maximization

$$\max_{\left\{k^c_{m,t}, n^{c,d}_{P,m,t}, n^{c,d}_{I,m,t}\right\}} F^c_{m,t} \tag{3.43}$$

subject to demand function (3.42). Real wages and the real rental rate of capital are then given by

$$r^{k^c}_t = mc_t z^c_t \gamma^c \left(k^c_{m,t}\right)^{\gamma^c - 1} \left(\left(n^{c,d}_{P,m,t}\right)^{\alpha^c} \left(n^{c,d}_{I,m,t}\right)^{1-\alpha^c}\right)^{1-\gamma^c}, \tag{3.44}$$

$$w^c_{P,t} = mc_t z^c_t \left(1-\gamma^c\right) \alpha^c \left(k^c_{m,t}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,m,t}\right)^{\alpha^c} \left(n^{c,d}_{I,m,t}\right)^{1-\alpha^c}\right)^{(-\gamma^c)} \left(\frac{n^{c,d}_{P,m,t}}{n^{c,d}_{I,m,t}}\right)^{\alpha^c - 1}, \tag{3.45}$$

and

$$w^c_{I,t} = mc_t z^c_t \frac{(1-\gamma^c)}{(1-\alpha^c)^{-1}} \left(k^c_{m,t}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,m,t}\right)^{\alpha^c} \left(n^{c,d}_{I,m,t}\right)^{1-\alpha^c}\right)^{(-\gamma^c)} \left(\frac{n^{c,d}_{P,m,t}}{n^{c,d}_{I,m,t}}\right)^{\alpha^c}, \tag{3.46}$$

where mc_t is the firm's real marginal cost. From the optimality conditions, all firms m face the same prices of factors, and since they have access to the same technology, marginal cost is equal across all firms at every period t.

Firms are able to reoptimize their prices as in Calvo (1983) and Yun (1996). Specifically, each firm faces a price rigidity with a non-zero probability ξ^{p^c} of being unable to adjust its nominal price in a given period. These firms are able to imperfectly index their price at rate ι^{p^c} to the steady-state inflation. The reoptimization probability is independently and identically distributed across firms and over time. Firms maximize the expected present value of their real dividends. Therefore, in setting their price in period t, firms take into account the fact that they may have to wait some time until they are able to reoptimize their price. In particular, the probability of not reoptimizing between dates t and $t+s$ is $\left(\xi^{p^c}\right)^s$. Since all reoptimizing firms face the same problem, they will all choose $\tilde{p}^c_t$ as the real optimal price. To maximize the expected present value of their real dividends, the producers of intermediate goods in the consumption sector must meet the following first-order necessary condition with respect to $\tilde{P}^c_t$[16]:

$$E_t \sum_{s=0}^{\infty} \left(\beta_P \xi^{p^c}\right)^s \frac{\lambda^c_{P,t+s}}{\lambda^c_{P,t}} \left(\frac{\tilde{P}^c_t}{P^c_t}\right)^{-\theta^c} \prod_{k=1}^{s} \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi^c_{t+k}}\right)^{-\theta^c} y^c_{t+s} \left[\frac{\theta^c - 1}{\theta^c} \left(\frac{\tilde{P}^c_t}{P^c_t}\right) \prod_{k=1}^{s} \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi^c_{t+k}}\right) - mc_{t+s}\right] = 0,$$

with $\beta^s_P \frac{\lambda^c_{P,t+s}}{\lambda^c_{P,t}} \frac{P^c_t}{P^c_{t+s}} MC^j_{t+s}$ being the Lagrange multiplier on demand function (3.42), and MC^j_{t+s} is the firm's nominal marginal cost. Since firms are assumed to act in the best interest of their owners (i.e. the lenders), the Lagrange multiplier is the marginal rate of substitution for consumption goods over time (i.e. equation (3.21)). According to this

[16]The Lagrangian can be found in Appendix 3.3.

expression, optimizing firms set nominal prices so that average future expected marginal revenues equate average future expected marginal costs.

The expression above does not have a direct recursive formulation, making the computation difficult. However, writing the price-setting equation in recursive form eases this process. To do so, we need to define intermediate variables $x_t^{c,1}$ and $x_t^{c,2}$:

$$
\begin{aligned}
x_t^1 =& \frac{\theta^c - 1}{\theta^c} \tilde{p}_t^{c\,1-\theta^c} y_t^c + \beta_P \xi^{p^c} E_t \left[\frac{\lambda_{P,t+1}^c}{\lambda_{P,t}^c} \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi_{t+1}^c} \right)^{1-\theta^c} \left(\frac{\tilde{p}_t^c}{\tilde{p}_{t+1}^c} \right)^{1-\theta^c} x_{t+1}^1 \right], \qquad (3.47) \\
x_t^2 =& \tilde{p}_t^{c\,-\theta^c} y_t^c mc_{m,t} + \beta_P \xi^{p^c} E_t \left[\frac{\lambda_{P,t+1}^c}{\lambda_{P,t}^c} \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi_{t+1}^c} \right)^{-\theta^c} \left(\frac{\tilde{p}_t^c}{\tilde{p}_{t+1}^c} \right)^{-\theta^c} x_{t+1}^2 \right], \\
x_t^1 =& x_t^2.
\end{aligned}
$$

Given that the opportunity to reoptimize prices arrives probabilistically for each firm in each period, the aggregate price index (3.39) can be written in this recursive form:

$$
1 = \left(1 - \xi^{p^c}\right) \left(\tilde{p}_t^c\right)^{1-\theta^c} + \xi^{p^c} \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi_t^c} \right)^{1-\theta^c}. \qquad (3.48)
$$

3.2.2.2 Housing sector

A representative firm produces houses in a perfectly competitive environment. Its production function is

$$
y_t^h = z_t^h \left(u_t^{k^h} k_{t-1}^h\right)^{\gamma^h} l_{t-1}^{\gamma^l} \left(\left(n_{P,t}^{h,d}\right)^{\alpha^h} \left(n_{I,t}^{h,d}\right)^{1-\alpha^h} \right)^{1-\gamma^h-\gamma^l}, \qquad (3.49)
$$

where y_t^h is the total production for the housing sector, $n_{i,t}^{h,d}$ are the number of hours of work demanded by the firm for both types of workers, z_t^h is the sector-wide total factor productivity, $u_t^{k^h} k_{t-1}^h$ is the capital stock rented, and l_{t-1} is the land stock rented.[17] Also,

[17] Since we assume a representative firm, to simplify the notation, we have already included the fact that the firm rents all the available capital in the sector, represented by $u_t^{k^h} k_{t-1}^h$, and all the available land, represented by l_{t-1}.

γ^h is the capital share of income, α^h is the lenders' share of labour income and γ^l is the land share of income.[18] The nominal profits (i.e. dividends) of the firm are denoted by

$$F_t^h = Q_t^h y_t^h - R_t^{k^h} u_t^{k^h} k_{t-1}^h - R_t^l l_{t-1} - W_{P,t}^h n_{P,t}^{h,d} - W_{I,t}^h n_{I,t}^{h,d}. \tag{3.50}$$

The firm's objective is a static problem of profit maximization

$$\max_{\left\{u_t^{k^h} k_{t-1}^h, n_{P,t}^{h,d}, n_{I,t}^{h,d}\right\}} F_t^h \tag{3.51}$$

subject to (3.49). Real wages and real rental rates of capital and land are then given by

$$r_t^{k^h} = q_t^h z_t^h \gamma^h \left(u_t^{k^h} k_{t-1}^h\right)^{\gamma^h - 1} l_{t-1}^{\gamma^l} \left(\left(n_{P,t}^{h,d}\right)^{\alpha^h} \left(n_{I,t}^{h,d}\right)^{1-\alpha^h}\right)^{1-\gamma^h-\gamma^l}, \tag{3.52}$$

$$r_t^l = q_t^h z_t^h \gamma^l \left(u_t^{k^h} k_{t-1}^h\right)^{\gamma^h} l_{t-1}^{\gamma^l - 1} \left(\left(n_{P,t}^{h,d}\right)^{\alpha^h} \left(n_{I,t}^{h,d}\right)^{1-\alpha^h}\right)^{1-\gamma^h-\gamma^l}, \tag{3.53}$$

$$\begin{aligned} w_{P,t}^h =& q_t^h z_t^h \left(1 - \gamma^h - \gamma^l\right) \alpha^h \left(u_t^{k^h} k_{t-1}^h\right)^{\gamma^h} l_{t-1}^{\gamma^l} \times \\ & \left(\left(n_{P,t}^{h,d}\right)^{\alpha^h} \left(n_{I,t}^{h,d}\right)^{1-\alpha^h}\right)^{-\gamma^h-\gamma^l} \left(\frac{n_{P,t}^{h,d}}{n_{I,t}^{h,d}}\right)^{\alpha^h - 1}, \end{aligned} \tag{3.54}$$

and

$$\begin{aligned} w_{I,t}^h =& q_t^h z_t^h \left(1 - \gamma^h - \gamma^l\right) \left(1 - \alpha^h\right) \left(u_t^{k^h} k_{t-1}^h\right)^{\gamma^h} l_{t-1}^{\gamma^l} \times \\ & \left(\left(n_{P,t}^{h,d}\right)^{\alpha^h} \left(n_{I,t}^{h,d}\right)^{1-\alpha^h}\right)^{-\gamma^h-\gamma^l} \left(\frac{n_{P,t}^{h,d}}{n_{I,t}^{h,d}}\right)^{\alpha^h}. \end{aligned} \tag{3.55}$$

3.2.2.3 Labour input

The labour input used by the firms in a given sector, denoted by $n_{i,t}^{j,d}$, is assumed to be a composite made of a continuum of differentiated labour services $n_{i,l,t}^{j,d}$. In the case

[18] In the calibration, we will assume that $\alpha^h = \alpha^c = \alpha$

of the consumption sector, we need integrate labour demand over all intermediate firms $m \in [0,1]$, which yields

$$n_{i,l,t}^{c,d} = \int_0^1 \left(n_{i,l,m,t}^{c,d}\right) dm, \tag{3.56}$$

where i and l have the same meaning as before. The aggregated labour demand for agents of type i in sector j is given by

$$n_{i,t}^{j,d} = \left[\int_0^1 \left(n_{i,l,t}^{j,d}\right)^{\frac{\theta^{n^j}-1}{\theta^{n^j}}} dl\right]^{\frac{\theta^{n^j}}{\theta^{n^j}-1}}. \tag{3.57}$$

By solving the cost minimization problem

$$\min_{\left\{n_{P,l,t}^{j,d}, n_{I,l,t}^{j,d}\right\}} \int_0^1 W_{P,l,t}^j n_{P,l,t}^{j,d} dl + \int_0^1 W_{I,l,t}^j n_{I,l,t}^{j,d} dl, \tag{3.58}$$

the optimal demand for labour type i in labour market l at time t is

$$n_{i,l,t}^{j,d} = \left(\frac{W_{i,l,t}^j}{W_{i,t}^j}\right)^{-\theta^{n^j}} n_{i,t}^{j,d}, \tag{3.59}$$

where the nominal wage index is given by

$$W_{i,t}^j = \left[\int_0^1 \left(W_{i,l,t}^j\right)^{1-\theta^{n^j}} dl\right]^{\frac{1}{1-\theta^{n^j}}}. \tag{3.60}$$

Given that the opportunity to reoptimize wages arrives probabilistically for each households in each period, the aggregate wage index (3.60) for agent i in sector j can be written in this recursive form:

$$\left(w_{i,t}^j\right)^{1-\theta^{n^j}} = \left(1-\xi^{w^j}\right)\left(\tilde{w}_{i,t}^j\right)^{1-\theta^{n^j}} + \xi^{w^j}\left(\frac{w_{i,t-1}^j \left(\pi^c\right)^{\iota^{w^j}}}{\pi_t^c}\right)^{1-\theta^{n^j}}. \tag{3.61}$$

3.2.3 Financial Intermediaries

We assume that households use financial intermediaries because they cannot borrow and lend with each other directly. Financial intermediaries accept deposit d_t from lenders at the cost R_t^d and lend to borrowers m_t at rate R_t^m. The spread between rates on loans and deposits reflects a time-varying intermediation cost and it is assumed to be a deadweight loss to the economy. Financial intermediaries are assumed to be perfectly competitive. To maximize the expected present value of their real dividends, financial intermediaries must solve

$$\max_{\{d_t,m_t\}} E_t \sum_{s=0}^{\infty} (\beta_P)^s \left[\frac{\lambda_{P,t+s}^c}{\lambda_{P,t}^c}\frac{P_t^c}{P_{t+s}^c}\right] F_{t+s}^{fi}$$

subject the balance sheet (in real terms)

$$d_t + \frac{1}{\phi^m}\sum_{s=1}^{\phi^m}\frac{m_{t-s}}{\prod_{v=-s}^{0}\pi_{t+v}^c} + \sum_{s=1}^{\phi^m}\left(R_{t-s}^m - 1\right)\left(\frac{\phi^m - s + 1}{\phi^m}\right)\frac{m_{t-s}}{\prod_{v=-s}^{0}\pi_{t+v}^c} = \tag{3.62}$$
$$m_t + \frac{1}{\phi^m}\sum_{s=1}^{\phi^m}\frac{d_{t-s}}{\prod_{v=-s}^{0}\pi_{t+v}^c} + \sum_{s=1}^{\phi^m}\left(R_{t-s}^d - 1\right)\left(\frac{\phi^m - s + 1}{\phi^m}\right)\frac{d_{t-s}}{\prod_{v=-s}^{0}\pi_{t+v}^c} + f_t^{fi} + \epsilon_t^{R^m} m_t.$$

As documented by Campbell (2013), in many countries (as in Canada in particular), the vast majority of housing loans are long-term fixed-rate mortgages. We then incorporate a simple form of this type of contract with one type of mortgage being available, with principal being reimburse linearly over ϕ^m periods. The deposit is also of the same form.[19]

By taking the first-order necessary conditions for d_t and m_t yields the solution for R_t^m

$$R_t^m = \frac{1 + \epsilon_t^{R^m} - \frac{1}{\phi^m}\sum\limits_{s=0}^{\phi^m}\beta_P^s E_t\left[\frac{\lambda_{P,t+s}^c}{\lambda_{P,t}^c}\frac{1}{\prod_{v=1}^{s}\pi_{t+v}^c}\right]}{\sum\limits_{s=0}^{\phi^m}\frac{\phi^m - s + 1}{\phi^m}\beta_P^s E_t\left[\frac{\lambda_{P,t+s}^c}{\lambda_{P,t}^c}\frac{1}{\prod_{v=1}^{s}\pi_{t+v}^c}\right]}.$$

[19] This hypothesis is not central for our results. We tried one-period variable-rate deposit and it yielded similar results.

3.2.4 Monetary Policy

The central bank implements a Taylor-type (Taylor, 1993) monetary policy rule with interest smoothing:

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\rho_r} \left(\frac{\pi_t^c}{\epsilon_t^{\pi^c}}\right)^{(1-\rho_r)\rho_{\pi^c}} \left(\frac{Y_t}{Y_{ss}}\right)^{(1-\rho_r)\rho_y} \exp\left(\varepsilon_t^R\right). \tag{3.63}$$

The monetary authority adjusts the nominal gross interest rate R_t from its steady-state value in response to deviations of inflation π_t^c from its target, deviations of the GDP (Y_t) from its steady state value, and the *i.i.d.* monetary policy innovation ε_t^R with variance $\sigma_{\varepsilon^R}^2$. ρ_r, ρ_{π^c} and ρ_y are the persistence parameter, and the inflation and output response parameters, respectively. The central bank's target, $\epsilon_t^{\pi^c}$, is assumed to be an exogenous time varying process subject to shocks, as in Smets and Wouters (2003) and Adolfson et al. (2007). The inflation targeting has been implemented in 1991 in Canada, therefore this model specification can help capturing the response of R_t to movements in π_t^c in the first third of our sample.

3.2.5 Exogenous Processes

All the exogenous processes in the model introduced earlier follow

$$\ln \Theta_t = (1-\rho_\Theta)\,\Theta_{ss} + \rho_\Theta \Theta_{t-1} + \varepsilon_t^\Theta, \tag{3.64}$$

where $\Theta_t = \left\{\epsilon_t^b, \epsilon_t^h, \epsilon_t^n, \epsilon_t^{\pi^c}, \epsilon_t^{R^m}, l_t, z_t^c, z_t^h, z_t^{i^k}\right\}$ are the exogenous processes, Θ_{ss} are their respective steady-state values, and ρ_Θ their respective persistence parameters. The structural shocks in the model, $\varepsilon_t^\Theta = \left\{\varepsilon_t^{\epsilon^b}, \varepsilon_t^{\epsilon^h}, \varepsilon_t^{\epsilon^n}, \varepsilon_t^{\epsilon^{\pi^c}}, \varepsilon_t^{\epsilon^{R^m}}, \varepsilon_t^l, \varepsilon_t^{z^c}, \varepsilon_t^{z^h}, \varepsilon_t^{z^{i^k}}\right\}$ along with the monetary policy innovation ε_t^R, are all zero-mean *i.i.d.* shocks with process-specific variance σ_Θ^2, and are uncorrelated contemporaneously and at all leads and lags.

3.2.6 Market Clearing

Consumption sector The aggregations in the production and labour markets follow similar processes introduced in the New Keynesian literature. Integrating both sides of the intermediate goods production technology (3.40) yields

$$\begin{aligned}\int_0^1 \left(y^c_{m,t}\right) dm =& \int_0^1 z^c_t \left(k^c_{m,t}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,m,t}\right)^{\alpha^c} \left(n^{c,d}_{I,m,t}\right)^{1-\alpha^c}\right)^{1-\gamma^c} dm \\ =& z^c_t \left(u^{k^c}_t k^c_{t-1}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,t}\right)^{\alpha^c} \left(n^{c,d}_{I,t}\right)^{1-\alpha^c}\right)^{1-\gamma^c}.\end{aligned} \tag{3.65}$$

Substituting $y^c_{m,t}$ in (3.65) and using demand function (3.42), we get

$$\left[\int_0^1 \left(\frac{P^c_{m,t}}{P^c_t}\right)^{-\theta^c} dm\right] y^c_t = s^y_t y^c_t = z^c_t \left(u^{k^c}_t k^c_{t-1}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,t}\right)^{\alpha^c} \left(n^{c,d}_{I,t}\right)^{1-\alpha^c}\right)^{1-\gamma^c}, \tag{3.66}$$

where s^y_t captures the inefficiencies associated with price dispersion arising from the price rigidity *à la* Calvo (1983). Schmitt-Grohé and Uribe (2007) show that these price dispersion indexes can be defined as

$$s^y_t = (1-\xi^c)\left(\tilde{p}^c_t\right)^{-\theta^c} + \xi^c \left(\frac{(\pi^c)^{\iota^{p^c}}}{\pi^c_t}\right)^{-\theta^c} s^y_{t-1}. \tag{3.67}$$

The market clearing condition for the consumption sector is therefore

$$y^c_t = c_t + q^{k^c}_t i^{k^c}_t + q^{k^h}_t i^{k^h}_t + \epsilon^{R^m}_t m_t, \tag{3.68}$$

where $c_t = c_{P,t} + c_{I,t}$. Finally, the real profits are

$$f^c_t = y^c_t - w^c_{P,t} n^{c,d}_{P,t} - w^c_{I,t} n^{c,d}_{I,t} - r^{k^c}_t u^{k^c}_t k^c_{t-1}. \tag{3.69}$$

Housing sector Given that total production, as expressed by (3.49), must satisfy the aggregate demand for the sector

$$y_t^h = i_{P,t}^h + i_{I,t}^h, \tag{3.70}$$

the real profits are

$$f_t^h = q_t^h y_t^h - w_{P,t}^h n_{P,t}^{h,d} - w_{I,t}^h n_{I,t}^{h,d} - r_t^{k^h} u_t^{k^h} k_{t-1}^h - r_t^l l_{t-1}, \tag{3.71}$$

and the total housing stock is $h_t = h_{P,t} + h_{I,t}$.

Labour input The nominal wage rigidity induces a loss in the number of hours worked supplied due to nominal wage dispersions. Schmitt-Grohé and Uribe (2007) show that these price dispersions, for agents of type i in sector j, can be expressed as

$$s_{i,t}^j = \left(1 - \xi^{w^j}\right) \left(\frac{\tilde{w}_{i,t}^j}{w_{i,t}^j}\right)^{-\theta^{n^j}} + \xi^{w^j} \left(\frac{\left(\pi^c\right)^{\iota^{w^j}}}{\pi_t^c}\right)^{-\theta^{n^j}} \left(\frac{w_{i,t-1}^j}{w_{i,t}^j}\right)^{-\theta^{n^j}} s_{i,t-1}^j, \tag{3.72}$$

and the labour supply-demand relation is given by $n_{i,t}^j = n_{i,t}^{j,d} s_{i,t}^j$.

Aggregate Economy The real GDP is therefore given by

$$y_t = y_t^c + q_t^h y_t^h. \tag{3.73}$$

3.2.7 Competitive Equilibrium

An (imperfectly) competitive equilibrium is an allocation for :

- the lenders: $\mathcal{C}_P = \left\{c_{P,t}, h_{P,t}, n_{P,t}^j, b_{P,t}, i_t^{k^j}, k_t^j, u_t^{k^j}, d_t\right\}_{t=0, j\in\{c,h\}}^{\infty}$,
- the borrowers: $\mathcal{C}_I = \left\{c_{I,t}, h_{I,t}, n_{I,t}^j, b_{I,t}, m_t\right\}_{t=0, j\in\{c,h\}}^{\infty}$,
- the firms in consumption sector: $\mathcal{F}^c = \left\{y_{m,t}^c, K_{m,t}^c, n_{i,m,t}^{c,d}, F_{m,t}^c\right\}_{t=0, m\in[0,1], i\in\{P,I\}}^{\infty}$,
- the firms in housing sector: $\mathcal{F}^h = \left\{y_t^h, k_t^h, n_{i,t}^{h,d}, F_t^h, l_t\right\}_{t=0, i\in\{P,I\}}^{\infty}$, and

- prices system: $\mathcal{P} = \left\{R_t, R_t^m, R_t^d, \pi_t^c, \tilde{p}_t^c, q_t^h, q_t^l, w_{i,t}^j, \tilde{w}_{i,t}^j, q_t^{kj}\right\}_{t=0, i\in\{P,I\}, j\in\{c,h\}}^{\infty}$,

such that, given initial conditions on predetermined variables, the exogenous processes, and the prices system, the allocations $\mathcal{C}_P$, $\mathcal{C}_I$, $\mathcal{F}^c$ and $\mathcal{F}^h$ solve the households and firms problems, and all market clearing conditions in Section 3.2.6 are satisfied.

3.3 Empirical Strategy

In order to evaluate the performance of the model, we use a combination of calibrated and estimated parameters. Our choice to calibrate some of the parameters was mainly based on the lack of data for some of the model variables, particularly those describing the production functions and the wealth distribution. This section first describes our calibration approach, then presents the details regarding the estimation procedure, and concludes with a presentation of the data.

3.3.1 Calibration

The model is calibrated on a quarterly basis. Table 3.1 summarizes our calibration, while Table 3.2 displays the steady-states of the model and observed values of corresponding data. We calibrated this set of parameters because they are either difficult to estimate given the information contained in the model[20] or because they are better identified using other information. For instance, some parameters are set to achieve target values for steady-states while others are set to commonly used values in the literature.

We set the steady-state annual inflation rate at 2 percent, this value being the target of the inflation-control policy implemented by the Bank of Canada. The steady-state of nominal and real interest rates reflect the lender's degree of time preference, β_P, and the

[20]For identification testing, we compute estimates of the Fisher information matrix. The Fisher matrix is a property of the model itself, and is independent of any data. It represents the maximum amount of information we can find in the data assuming the data are really generated by the model DGP. We compute two approaches: a time-domain one, and a frequency-domain one, and use a singular value decomposition to learn more about which parameters (or combinations of them) are identified the best or the worst. In our case, the intratemporal elasticity of substitution between sectoral labour supplies, the depreciation rates, the intratemporal elasticity of substitution across different varieties of intermediate goods and the wage-elasticities of demand has been revealed to be not or weakly identifiable.

steady-state gross inflation rate. We use an annual real rate of return of 3.07 percent, which is the average over our sample. This implies that $\left(\frac{\pi^c_{ss}}{\beta_P}\right)^4$ is equal to 1.0307, which yields a β_P of 0.9928. As for the calibration of the borrower's time discount factor, we choose a value of 0.9847, which is the inflation rate divided by R^m_t and is in range of other studies that estimated or calibrated this parameter (Krusell and Smith, 1998; Iacoviello, 2005; Iacoviello and Neri, 2010; Gelain et al., 2013) and which translates into a desire for borrowing. It is important to highlight that we are departing here from a common strategy used in previous studies estimating models of housing dynamics and which consists of assuming zero steady-state inflation. Given that, up to the first order, the steady-state represents the unconditional mean of the variables, our approach has the advantage of centering the model closer to the unconditional mean in the data.

The ratio of patient households relative to impatient households (α) is 0.25, the former representing the top quartile of households in the model economy. Parameter α determines the labour share of income and, indirectly, the real estate wealth. In the model, patient households own all the physical capital wealth. By setting α at 0.25, the patient households own 75 percent of total wealth, which is broadly in line with financial and income data[21], and mortgage debt as a share of GDP is 0.92 (in the top of the distribution in our sample). It is important to highlight that we are departing here from the commonly used value in the literature, which is 0.79 (Iacoviello and Neri (2010); Lambertini et al. (2010b, 2013). By conducting identification tests, we found that it was not possible to identify this parameter in the absence of actual wealth data.

[21]See the *Survey of Financial Security* from Statistics Canada and the *World Top Income Database* available on Emmanuel Saez's website.

Table 3.1: CALIBRATED PARAMETERS

Parameter	Value	Parameter	Value
Households			
δ^h	0.011		
Lenders		*Borrowers*	
β_P	0.9928	β_I	0.9847
θ_P^x	0.4	θ_I^x	0.4
η_P	2.0	η_I	1.5
θ_P^n	10.0	θ_I^n	10.0
$\delta_0^{k^c}$	0.025		
$\delta_1^{k^c}$	0.0335		
$\delta_0^{k^h}$	0.03		
$\delta_1^{k^h}$	0.0385		
Production			
α	0.25		
Consumption sector		*Housing sector*	
γ^c	0.25	γ^h	0.1
θ^c	7.67	γ^l	0.35
θ^{n^c}	7.67	θ^{n^h}	7.67
Policy and Steady-state			
ω_{ss}	0.85	ϵ_{ss}^h	0.8
π_{ss}^c	1.005	ϵ_{ss}^n	7.0
l_{ss}	1.0	$\epsilon_{ss}^{\pi^c}$	1.005
$u_{ss}^{k^c}$	1.0	$\epsilon_{ss}^{R^m}$	0.066
$u_{ss}^{k^h}$	1.0	z_{ss}^c	1.0
ϵ_{ss}^b	1.0	z_{ss}^h	1.0
		$z_{ss}^{i^k}$	1.0

Following Iacoviello and Neri (2010), the quarterly depreciation rates for housing, capital in the consumption sector and capital in the housing sector are set at 0.011, 0.025 and 0.03, respectively, implying annual depreciation rates of 4.06 percent, 10.38 percent and 12.55 percent, respectively. Likewise, the prices and wages markups θ^c and θ^{n^j} are set at 7.67, which yields steady-state mark-ups of 15 percent for intermediate goods producers and households.

Table 3.2: STEADY-STATE RATIOS

Variable	Model Definition	Data				Model
		Mean	Std	Min	Max	
Inflation Rate	$100\left((\pi^c)^4-1\right)$	2.42	1.34	-0.55	6.39	2.00
Interest Rate						
Nominal Short-Term	$100\left(R^4-1\right)$	5.50	3.48	0.20	13.57	5.50
Nominal Long-Term	$100\left((R^m)^4-1\right)$	8.44	2.79	4.25	14.47	8.41
Real Short-Term	$100\left(R^4-(\pi^c)^4\right)$	3.07	2.92	-2.78	10.62	3.50
Flow as a share of GDP						
Consumption	$100\left(\frac{c}{y}\right)$	74.81	1.86	70.75	78.51	72.52
Non-Housing Investment	$100\left(\frac{\left(q^{k^c}i^{k^c}+q^{k^h}i^{k^h}\right)}{y}\right)$	16.08	1.28	12.93	18.06	15.42
Housing Investment	$100\left(\frac{q^h y^h}{y}\right)$	9.10	1.33	6.91	11.31	9.68
Stock to GDP						
Capital	$\frac{\left(q^{k^c}k^c+q^{k^h}k^h\right)}{4y}$	1.44	0.10	1.30	1.66	1.53
Residential Structures	$\frac{q^h y^h}{4y}$	1.24	0.12	1.05	1.46	2.20
Land	$\frac{q^l l}{4y}$	0.91	0.20	0.66	1.32	1.00
Mortgage Debt	$\frac{b_i}{4y}$	0.65	0.15	0.39	0.94	0.92
Hours Worked						
Consumption	$\frac{n^c}{\left(n^c+n^h\right)}$	95.11	0.57	93.7	95.93	90.00
Housing	$\frac{n^h}{\left(n^c+n^h\right)}$	4.89	0.57	4.07	6.30	10.00

The capital share of income in the consumption sector, γ^c, is set 0.25. In the housing sector, we set the capital and land share of income γ^h and γ^l at 0.10 and 0.35, respectively. These factor shares, along with a weight of housing service in the utility function ϵ^h_{ss} of 0.8, the intratemporal elasticities $\theta^x_P = \theta^x_I = 0.4$ and the depreciation rates, imply steady-state ratios of consumption, non-housing investment and housing investment to real GDP of approximately 73 percent, 15 percent and 10 percent, respectively. Moreover, these calibration choices imply ratios of business capital and housing wealth (together with α) to annual GDP of around 1.5 and 2.2, respectively. Finally, along with the estimated parameters, the land share of income implies that the value of residential land is around 100 percent of GDP, a value close to the empirical data. The parameters η_P and η_I are set at 2.0 and 1.5, respectively, and the steady-state ϵ^n_{ss} is set so the steady-state labour supply is 0.37 for lenders and 0.45 for borrowers. The intratemporal elasticity of substitution between sectoral labour supplies are set at 10 for both households, yielding a share of total hours worked of 0.90 in the consumption sector.

Finally, the loan-to-value ratio is set at 0.85, which is the average value in Canada over the last 30 years, while $\epsilon_{ss}^{R^m}$ is set at 0.066 to match the average quarterly spread between the risk-free rate and the 5-year mortgage rate over the last 30 years.

3.3.2 Bayesian Approach

The noncalibrated parameters, collected in vector Ψ, are estimated by using a Bayesian approach (see DeJong et al. (2000); Lubik and Schorfheide (2006); An and Schorfheide (2007)). Given the sample $X^T = [x_1, \ldots, x_T]$, we are interested in the joint posterior distribution of the parameters, given the empirical data,

$$p\left(\Psi \mid X^T\right) = \frac{L\left(X^T \mid \Psi\right) p\left(\Psi\right)}{\int L\left(X^T \mid \Psi\right) p\left(\Psi\right) d\Psi},$$

where $L\left(X^T \mid \Psi\right)$ denotes de likelihood function, $p\left(\Psi\right)$ is the prior distribution, and the denominator is known as the marginal distribution likelihood of the data.

In order to compute the likelihood for a given set of parameters, we solve a log-linear approximation of the equilibrium conditions in the neighborhood of the non-stochastic steady-state (Blanchard and Kahn, 1980). The local approximation method is first-order accurate to the extent that we limit the exogenous processes to be bounded in the neighborhood of the steady state, and the solution is obtained using QZ decomposition (Klein, 2000; Sims, 2002).[22] The solution takes the form of a state-space model that is used to compute the likelihood function, and, given the linear solution and the assumption of normally-distributed shocks, the Kalman filter can be used to compute $L\left(X^T \mid \Psi\right)$.

Given the likelihood function, we characterize the posterior distribution in two steps. First, we transform the data (described below) into a form suitable for computing the likelihood

[22] We use a modified version of the Klein (2000) algorithm available in the IRIS Toolbox (http://iristoolbox.codeplex.com/).

function, we use prior distributions for the noncalibrated parameters to incorporate additional information into the estimation, and we maximize the posterior using numerical methods. Finally, we use a metropolis posterior simulator to evaluate the behaviour of the posterior distribution and to draw model parameters from the posterior distribution, using the mode obtained in the first step as a starting point.[23]

Prior Distributions The advantage of using priors is to take our *a priori* beliefs into account in estimating the parameters of the model. The choice of priors is described in the second, third and fourth columns of Tables 3.3 and 3.4 for the noncalibrated parameters, and Table 3.5 for the measurement errors. The priors' distributions are guided by the constraints in these parameters and are either consistent with previous studies (Levin et al., 2006; Del Negro et al., 2007; Justiniano et al., 2010; Iacoviello and Neri, 2010; Schmitt-Grohe and Uribe, 2012) or fairly diffuse and relatively uninformative.

To reflect their strict positivity, we set a Gamma prior on the investment adjustment costs (ϕ^{k^c} and ϕ^{k^h}) around 5 with a standard error of 2. We select a Beta prior for the Calvo price and wage parameters (ξ^{p^c}, ξ^{w^c} and ξ^{w^h}) and the inflation indexation parameters (ι^{p^c}, ι^{w^c} and ι^{w^h}) because they belong to the interval $[0, 1)$, and due to a lack of consensus on their values in the literature (Christiano et al., 2005; Smets and Wouters, 2007), we set the prior mean at 0.5, with a standard deviation of 0.22.

For all the persistence parameters governing the exogenous processes, we use a Beta prior with a mean equal to 0.80 and a standard deviation equal to 0.1.[24] For all innovations' and measurement errors' standard deviations, we use an Inverse-gamma prior with a mean equal to 0.1 and a standard deviation equal to 0.2. These priors are quite disperse and were chosen to generate volatility in the endogenous variables that is broadly in line with the data. Their covariance matrix is assumed to be diagonal.

For the monetary policy specification, we base our priors on a standard Taylor rule with

[23] We use an Adaptive random-walk Metropolis posterior simulator with 500 000 draws with 100 000 burn-in draws and target acceptance ratio of 0.234.

[24] A Beta prior with a mean equal to 0.5 and a standard deviation equal to 0.22 yields the same estimation results on these parameters.

interest rate smoothing that responds gradually to inflation and output gap. We use a Beta prior for ρ_r and ρ_y with means of 0.85 and 0.125 and standard deviations of 0.1 and 0.025, respectively, and a Gamma prior with mean of 1.75 and a standard deviation of 0.25 for ρ_{π^c}. These priors are in line with previous Canadian studies (Christensen et al., 2009; Dorich et al., 2013).

Finally, we also implement model priors (Andrle and Benes, 2013). Model priors are priors about the model's features and behavior as a system, such as the sacrifice ratio or the maximum duration of response of inflation to a particular shock, for instance. In our case, since we focus on housing-market related business cycles, we select correlation to be the most relevant model priors to implement. More specifically, we use the first to fourth-order cross-correlation between consumption, non-housing investment, housing investment, house price and mortgage debt, and we apply a Beta prior with the mean being the the sample first to fourth-order cross-correlation compute on data filtered using a Christiano-Fitzgerald filter (Christiano and Fitzgerald, 2003) with a frequency between 6 and 32 quarters and standard deviation set at 0.1.

Data To estimate the model, we use Canadian quarterly data for the period 1983Q2 to 2012Q2. The vector of observables used for the estimation includes fifteen variables: real consumption per capita, real residential investment per capita, real non-residential investment per capita, house price inflation, nominal short-term interest rate, nominal long-term interest rate, core CPI inflation rate, real mortgage debt per capita, capital price inflation, hours worked per capita, wage inflation and capacity utilization rate in the consumption sector, and hours worked per capita, wage inflation and capacity utilization rate in the housing sector. All series are expressed in annualized quarterly growth rate.[25]. Figure 3.1 plots the time series. A detailed description of the series used in the estimation is provided in Appendix 3.1. In addition, we include *i.i.d.* measurement errors for hours worked, wages and capacity utilization rate.

[25]We adjust for seasonality before any computation when necessary.

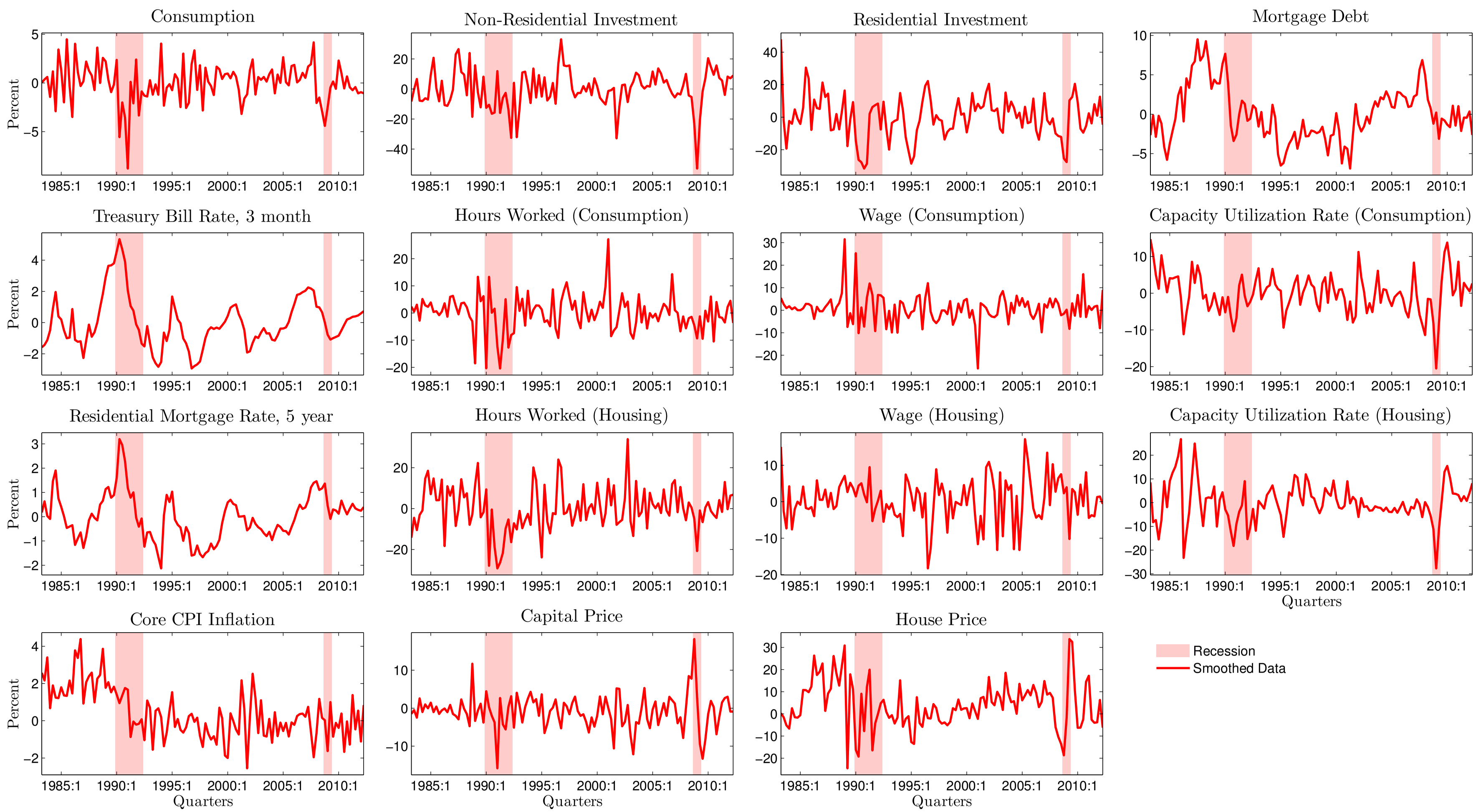


Figure 3.1: Data, from 1983Q2 to 2012Q2

It is relevant to notice that our set of observables includes more variables than most previous DSGE estimations for housing markets dynamic models. We consider series that are of general interest for policy analysis, such as consumption, investments, real wages, hours worked, inflation and interest rates, which are those usually used in the literature. Our data set also includes variables that may *a priori* help us identify several features of the model. For instance, disaggregated sectoral data, such as hours worked, wage and capacity utilization rates, will be useful in characterizing movements and correlation that are sectoral specific and could be hidden in aggregated data. Finally, mortgage debt contains information on the reallocation of debt between agents and the preference on consumption and housing services.

3.4 Empirical Results

In this section, we first describe the estimated posterior distribution, paying attention to the parameters describing the housing market dynamics. We then perform a posterior analysis to establish the extent to which the model can fit the data.

3.4.1 Posterior Distributions

The estimated posterior distributions of the noncalibrated parameters are summarized in Tables 3.3 and 3.4, while the measurement errors are presented in Table 3.5. In general terms, the information contained in the likelihood seems to significantly updates the assumed priors for all the parameters, given the marked differences in the statistics describing these two distributions.

The capital adjustment costs seem to differ across sectors. These results could imply that the model requires partial capital mobility across sectors in order to better approximate the data. Cumulated with the imperfect mobility in the labour market, this means that the real frictions caused by imperfect mobility play a significant role in the sub optimal allocation of resources relative to the perfect mobility scenario.

Table 3.3: Prior and Posterior Distributions of Structural Parameters

Parameter	Prior Distribution			Posterior Distribution				
	Distribution	Mean	Std	Mode	Std	5%	Median	95%
Households								
ξ^{w^c}	Beta	0.5	0.22	0.9693	0.0001	0.9693	0.9693	0.9695
ξ^{w^h}	Beta	0.5	0.22	0.9731	0.0001	0.9732	0.9733	0.9736
ι^{w^c}	Beta	0.5	0.22	0.7977	0.0003	0.7972	0.7978	0.7982
ι^{w^h}	Beta	0.5	0.22	0.7734	0.0043	0.7731	0.7793	0.7859
Lenders								
ϕ^{ik^c}	Gamma	5.0	2.0	1.7453	0.4863	1.3041	1.9188	2.5866
ϕ^{ik^h}	Gamma	5.0	2.0	3.0928	1.7438	2.4764	4.7582	8.1326
$\delta_2^{k^c}$	Beta	0.125	0.025	0.1017	0.0213	0.0786	0.1095	0.1479
$\delta_2^{k^h}$	Beta	0.125	0.025	0.1394	0.0213	0.1117	0.1412	0.1807
Production								
Consumption sector								
ξ^{p^c}	Beta	0.5	0.22	0.5567	0.0427	0.4431	0.5194	0.5914
ι^{p^c}	Beta	0.5	0.22	0.6300	0.2008	0.3358	0.8322	0.9428
Monetary policy								
ρ_r	Beta	0.85	0.1	0.8133	0.0448	0.6533	0.7361	0.8209
ρ_{π^c}	Gamma	1.75	0.25	2.4606	0.0076	2.4427	2.4511	2.4656
ρ_y	Beta	0.125	0.025	0.2736	0.0011	0.2704	0.2726	0.2740

With autoregressive parameters being in general higher that 0.93, the estimated exogenous processes are in general pretty persistent, except for the land stock process and the technology process in the consumption sector, with parameters equal to 0.8 and 0.78, respectively. Housing demand is the most persistent process with an autoregressive parameter equal to 0.9963. In terms of volatility, among the estimated standard error of the exogenous processes, the investment-specific shock seems to be the most volatile, followed the preference shock. However, we will see in the next section that those shocks are not the one that drive the forecast error variance decomposition, mainly because of their persistence.

Regarding parameters measuring nominal rigidities, the estimate of θ^{p^c} (0.55) implies that prices are reoptimized frequently, once every 2.25 quarters. However, given the positive value of the indexation parameter ($\iota^{p^c} = 0.63$), prices change every period, although not in response to change in nominal costs. As for wages, we find that stickiness in the housing sector ($\theta^{w^h} = 0.9731$) and in the consumption sector ($\theta^{w^c} = 0.9693$) are almost equal. While being reoptimized infrequently, once every 33 quarters, wages are indexed every period to compensate on average almost 80 percent of the steady-state inflation ($\iota^{w^h} = 0.7977$ and $\iota^{w^c} = 0.7734$).

Table 3.4: Prior and Posterior Distributions of Exogenous Processes

Parameter	Prior Distribution			Posterior Distribution				
	Distribution	Mean	Std	Mode	Std	5%	Median	95%
ρ_{ϵ^b}	Beta	0.8	0.1	0.9401	0.0171	0.9005	0.9342	0.9565
ρ_{ϵ^h}	Beta	0.8	0.1	0.9963	0.0018	0.9918	0.9954	0.9979
ρ_{ϵ^n}	Beta	0.8	0.1	0.9812	0.0059	0.9666	0.9735	0.9857
$\rho_{\epsilon^{\pi^c}}$	Beta	0.8	0.1	0.9459	0.0099	0.9234	0.9436	0.9562
$\rho_{\epsilon^{R^m}}$	Beta	0.8	0.1	0.9200	0.0826	0.6820	0.8459	0.9498
ρ_l	Beta	0.8	0.1	0.8036	0.0845	0.6598	0.8291	0.9351
ρ_{z^c}	Beta	0.8	0.1	0.7888	0.0424	0.7370	0.8132	0.8748
ρ_{z^h}	Beta	0.8	0.1	0.9959	0.0018	0.9926	0.9960	0.9982
$\rho_{z^{ik}}$	Beta	0.8	0.1	0.9352	0.0043	0.9634	0.9711	0.9772
σ_{ϵ^b}	Inv. Gamma	0.1	0.2	0.0277	0.0026	0.0199	0.0238	0.0283
σ_{ϵ^h}	Inv. Gamma	0.1	0.2	0.0048	0.0004	0.0042	0.0047	0.0054
σ_{ϵ^n}	Inv. Gamma	0.1	0.2	0.0257	0.0085	0.0195	0.0362	0.0470
$\sigma_{\epsilon^{\pi^c}}$	Inv. Gamma	0.1	0.2	0.0034	0.0002	0.0026	0.0029	0.0037
σ_{ϵ^R}	Inv. Gamma	0.1	0.2	0.0031	0.0003	0.0029	0.0034	0.0040
$\sigma_{\epsilon^{R^m}}$	Inv. Gamma	0.1	0.2	0.0278	0.0119	0.0177	0.0316	0.0565
σ_l	Inv. Gamma	0.1	0.2	0.0146	0.0034	0.0110	0.0159	0.0221
σ_{z^c}	Inv. Gamma	0.1	0.2	0.0072	0.0008	0.0051	0.0062	0.0077
σ_{z^h}	Inv. Gamma	0.1	0.2	0.0169	0.0012	0.0150	0.0168	0.0190
$\sigma_{z^{ik}}$	Inv. Gamma	0.1	0.2	0.0285	0.0014	0.0151	0.0172	0.0197

Finally, with a weight on inflation (ρ_{π^c}) of 2.46 and a fairly small weight on output gap ($\rho_y = 0.27$), estimates of the parameters of the monetary policy rule are in line with previous evidence (Christensen et al., 2009; Dorich et al., 2013). In terms of the three monetary disturbances, the shock to interest rate spread seems to be the most volatile, but less persistent than the shock to inflation targeting. The monetary policy shock standard error is perfectly with previous studies with Canadian data (Christensen et al., 2009; Dorich et al., 2013).

Table 3.5: Prior and Posterior Distributions of Measurement Errors

Parameter	Prior Distribution			Posterior Distribution				
	Distribution	Mean	Std	Mode	Std	5%	Median	95%
σ_{n^c}	Inv. Gamma	0.1	0.2	0.0702	0.0048	0.0634	0.0710	0.0790
σ_{n^h}	Inv. Gamma	0.1	0.2	0.2063	0.0136	0.1891	0.2100	0.2339
σ_{w^c}	Inv. Gamma	0.1	0.2	0.0652	0.0043	0.0588	0.0652	0.0729
σ_{w^h}	Inv. Gamma	0.1	0.2	0.0608	0.0040	0.0544	0.0602	0.0674
$\sigma_{u^{k^c}}$	Inv. Gamma	0.1	0.2	0.0545	0.0035	0.0488	0.0543	0.0604
$\sigma_{u^{k^h}}$	Inv. Gamma	0.1	0.2	0.0746	0.0052	0.0703	0.0775	0.0871

3.4.2 Second Moments

Figures 3.2, 3.3 and 3.4 present first- and second-order autocorrelation for sets of selected model variables, as well as cross-autocorrelation along with data moments. These figures present moments from data filtered using a Christiano-Fitzgerald filter to isolate periodicity between 6 and 32 quarters, along with filtered theoretical (asymptotic) and simulated moments, both based on the model evaluated using the posterior mode.[26] While the model overestimates the persistence (first- and second-order autocorrelation) of non-residential investment and wages in the housing sector and underestimates the persistence in hours worked in the consumption sector, it is able to replicate well all the other autocorrelations of the data, with the sample autocorrelation always being in the simulated distribution.

The model also matches both the sign and the level of the cross-correlation for most of the desired relationship being studied (Figure 3.4). The theoretical and simulated cross-correlation of consumption with housing investment and house prices are both in line, in sign and level, with their data counterparts. However, the correlation between consumption and non-residential investment is estimated to be negative and mild, whereas it is positive and large in the data. This is due to the construct of the model, which assumes that consumption and non-residential investment are both produce in the same sector,

[26]Simulated moments are computed based on 1000 Monte Carlo simulations.

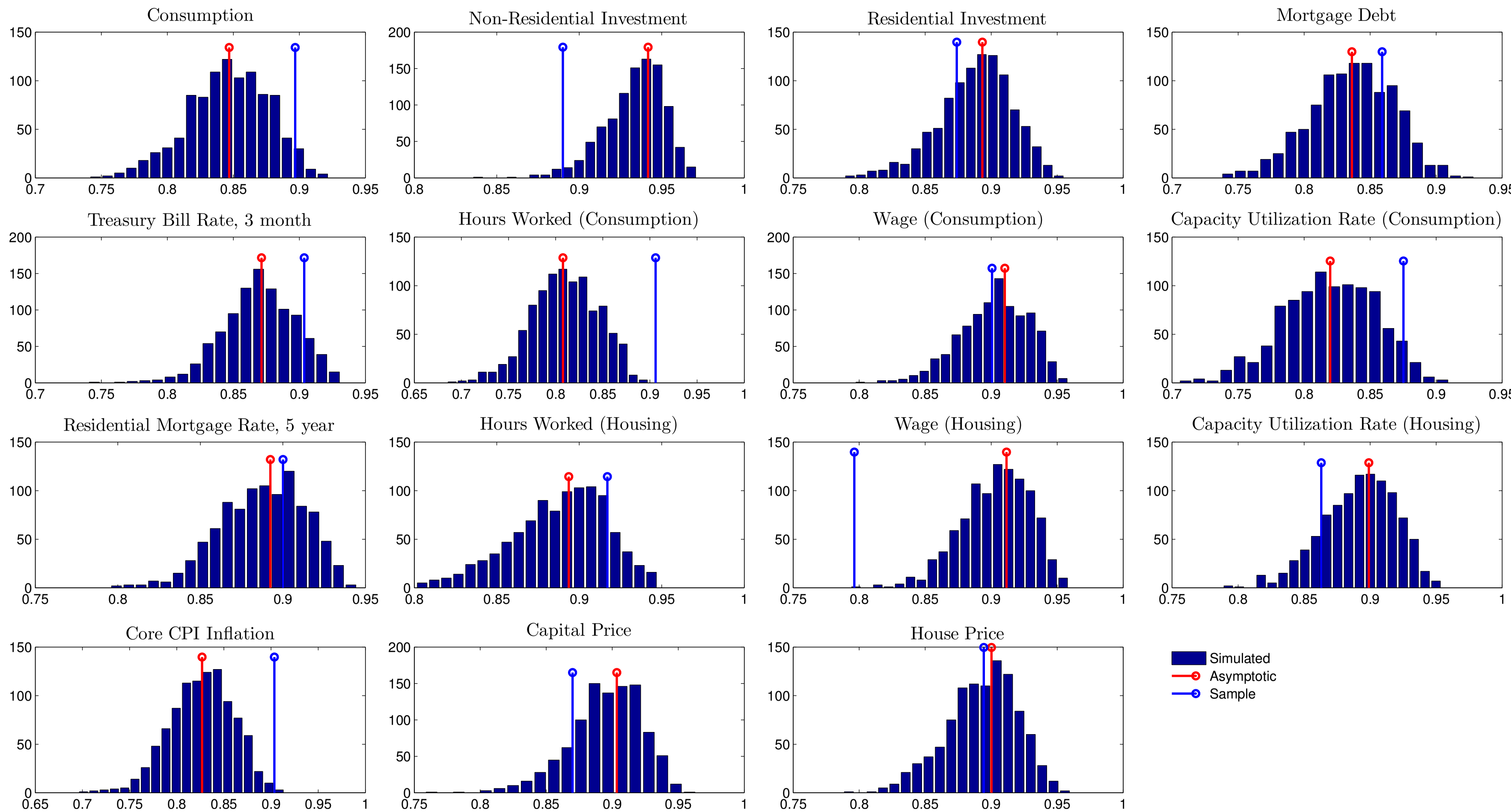


Figure 3.2: Theoretical, Simulated and Sample 1st Order Autocorrelation of Selected Model Variables

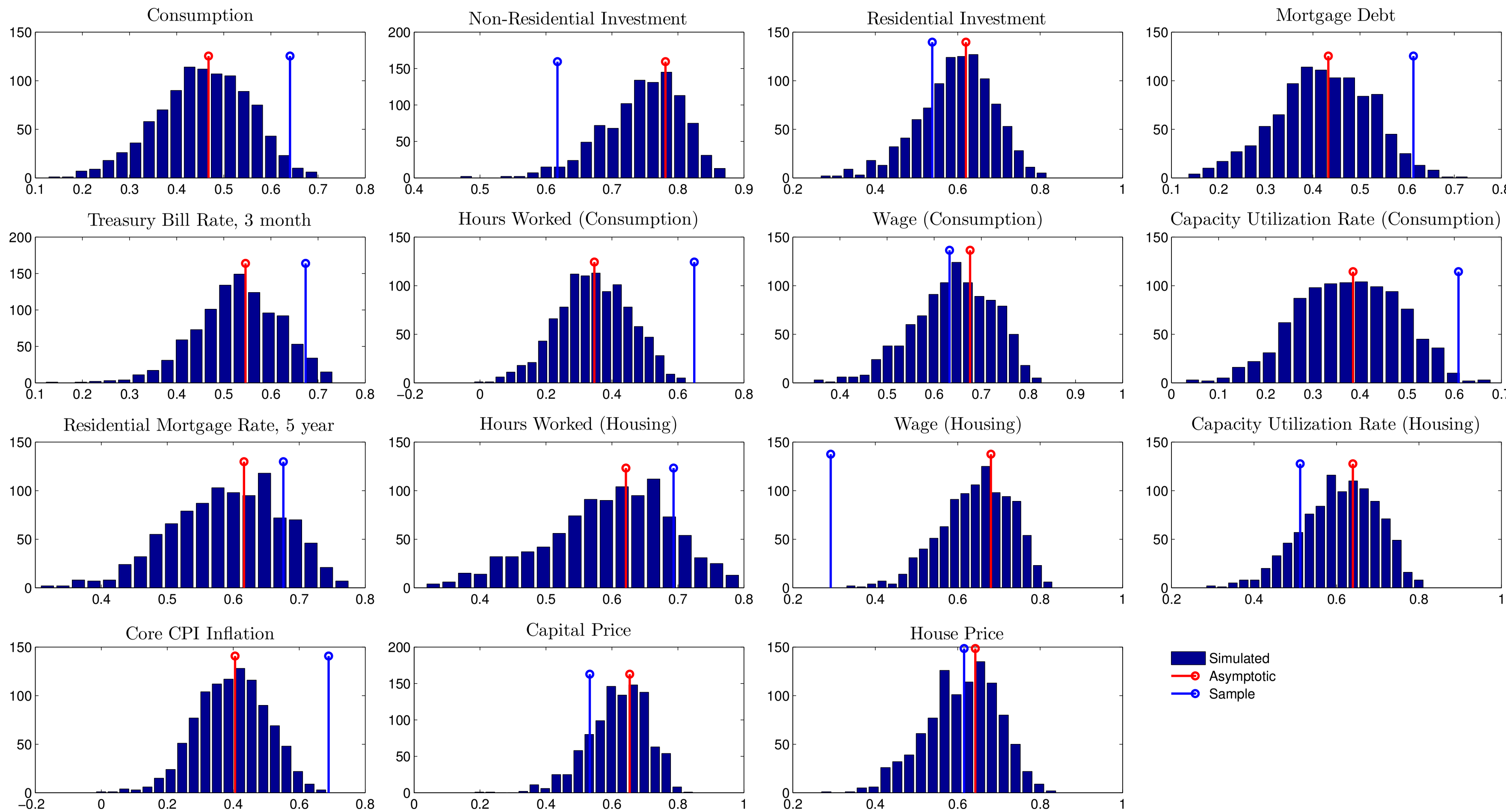


Figure 3.3: Theoretical, Simulated and Sample 2th Order Autocorrelation of Selected Model Variables

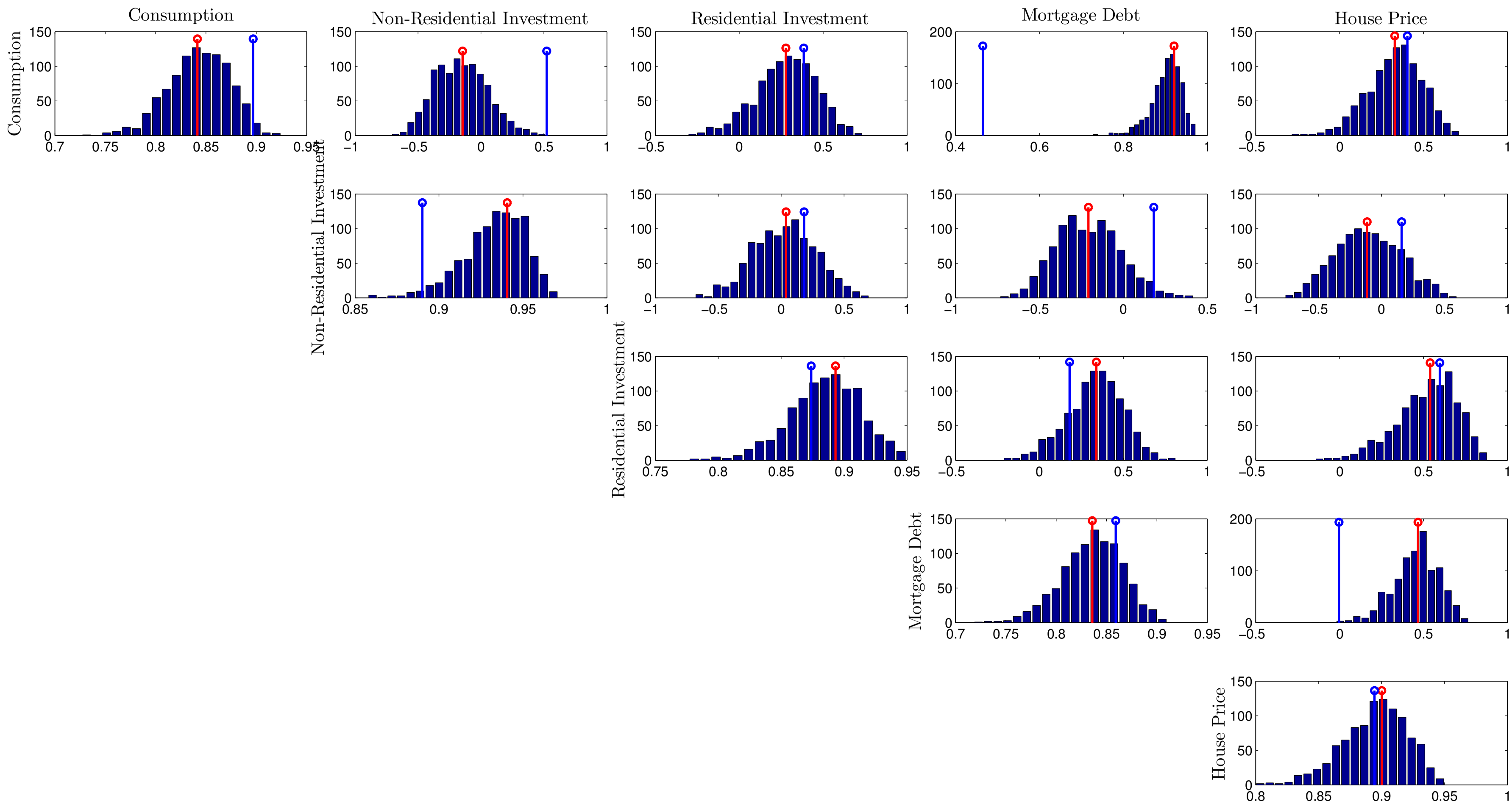


Figure 3.4: Theoretical, Simulated and Sample Cross-Correlation for Selected Model Variables

making reallocation easy between them. Perhaps this simple assumption makes it difficult to match a more complex production structure in the real economy. The estimated correlation between consumption and mortgage debt is also of the good sign, but is twice the correlation seen in the data. Lastly, the model tends to imply a positive contemporaneous correlation between house prices and mortgage debt, while in the data we only observe a lagged relationship. Overall, the model seems to properly replicate the behavior of the variables in terms of autocorrelation and cross-correlation, but has some difficulties matching dynamics the of consumption and investment in capital.

3.4.3 Variance Decomposition

After establishing the extent to which the estimated model can replicate the business cycle observations, we proceed with the variance decomposition. Table 3.6 presents the unconditional variance decomposition for both the observables (in growth rate) and the model variables representing the observables (in level) for all the shocks in the model, the last column being the sum of the contributions of all measurement errors. This section focuses on the model variables representing the observables (in level).

In terms of explaining the consumption fluctuations, the labour supplies shock and the inflation-targeting shock appear to be the most significant: over 60 percent of consumption volatility is due to the former, while the latter explains 16 percent. The labour supply shock affects directly the labour income of the agents, while the inflation-targeting shock cause, for a given increase in price level, variation in the reaction of the monetary policy across periods. In addition, both the housing demand shock and the investment specific shock explain over 8 percent of the consumption forecast error variance. The other drivers do not seem to play a significant role in explaining consumption fluctuations. These results are in contrast with other studies that identified technology in the consumption sector shocks and monetary policy shocks among the main drivers of consumption volatility.

Together, the housing demand shock and the technology shock in housing sector account for almost 80 percent of the total house price volatility and 79 percent of the total housing investment volatility.

Table 3.6: UNCONDITIONAL FORECAST ERROR VARIANCE DECOMPOSITION

Model variables (in level)	ε^{ϵ^b}	ε^{ϵ^h}	ε^{ϵ^n}	$\varepsilon^{\epsilon^{\pi^c}}$	ε^{ϵ^R}	$\varepsilon^{\epsilon^{R^m}}$	ε^l	ε^{z^c}	ε^{z^h}	$\varepsilon^{z^{i^k}}$	m.e.
Consumption	2.23	8.58	60.26	16.18	1.19	0.01	0.01	0.15	2.75	8.63	0.00
Capital Price	0.63	3.03	0.21	0.89	0.97	0.00	0.00	0.37	0.80	93.10	0.00
Non-Residential Investment	5.77	1.53	23.90	23.02	0.89	0.02	0.01	0.21	1.19	43.46	0.00
House Price	0.58	23.99	14.43	1.99	0.10	0.01	0.01	0.02	55.85	3.02	0.00
Residential Investment	0.52	56.40	14.78	6.19	0.27	0.01	0.31	0.14	19.14	2.25	0.00
Mortgage Debt	0.97	48.89	21.22	11.83	2.10	0.06	0.02	0.20	11.60	3.12	0.00
Core CPI Inflation	1.54	3.24	73.75	6.34	0.32	0.00	0.00	1.53	3.82	9.45	0.00
Treasury Bill Rate, 3 month	2.23	3.90	75.41	4.46	0.64	0.00	0.01	0.28	4.12	8.95	0.00
Residential Mortgage Rate, 5 year	2.07	2.81	78.56	3.25	0.10	0.03	0.00	0.04	3.95	9.17	0.00
Hours Worked (Consumption)	0.71	15.52	41.38	26.90	3.97	0.03	0.03	1.17	4.84	5.45	0.00
Wage (Consumption)	5.28	1.15	1.82	19.32	0.48	0.02	0.01	9.92	0.48	61.54	0.00
Capacity Utilization Rate (Consumption)	3.84	24.88	2.21	31.32	4.93	0.05	0.05	1.26	7.25	24.21	0.00
Hours Worked (Housing)	0.47	63.97	15.12	8.02	0.39	0.02	0.12	0.20	10.11	1.58	0.00
Wage (Housing)	3.05	10.20	52.75	5.75	0.06	0.00	0.00	1.41	4.26	22.51	0.00
Capacity Utilization Rate (Housing)	1.91	55.29	6.04	21.09	1.19	0.07	0.77	0.37	1.63	11.64	0.00
Data (in growth rate)	ε^{ϵ^b}	ε^{ϵ^h}	ε^{ϵ^n}	$\varepsilon^{\epsilon^{\pi^c}}$	ε^{ϵ^R}	$\varepsilon^{\epsilon^{R^m}}$	ε^l	ε^{z^c}	ε^{z^h}	$\varepsilon^{z^{i^k}}$	m.e.
Consumption	1.59	28.32	1.76	43.84	11.14	0.03	0.08	0.71	10.85	1.66	0.00
Capital Price	1.44	7.68	54.59	5.57	2.87	0.00	0.00	0.34	3.86	23.64	0.00
Non-Residential Investment	6.47	5.72	1.41	16.31	3.49	0.04	0.02	1.10	1.52	63.91	0.00
House Price	0.86	27.55	35.68	17.10	4.89	0.07	0.04	0.31	8.81	4.71	0.00
Residential Investment	0.23	40.05	1.97	21.85	7.18	0.10	6.41	0.39	21.17	0.65	0.00
Mortgage Debt	0.17	47.44	1.46	27.64	10.07	0.12	0.08	0.38	11.53	1.10	0.00
Core CPI Inflation	1.54	3.24	73.75	6.34	0.32	0.00	0.00	1.53	3.82	9.45	0.00
Treasury Bill Rate, 3 month	2.23	3.90	75.41	4.46	0.64	0.00	0.01	0.28	4.12	8.95	0.00
Residential Mortgage Rate, 5 year	2.07	2.81	78.56	3.25	0.10	0.03	0.00	0.04	3.95	9.17	0.00
Hours Worked (Consumption)	0.05	39.24	1.39	33.19	11.37	0.07	0.08	1.40	10.84	1.49	0.89
Wage (Consumption)	1.26	2.04	61.75	3.71	0.00	0.00	0.00	0.02	2.98	7.70	20.54
Capacity Utilization Rate (Consumption)	0.08	40.26	1.51	28.34	8.78	0.07	0.07	1.16	10.86	0.93	7.94
Hours Worked (Housing)	0.22	36.06	1.77	19.84	6.57	0.09	1.91	0.36	1.45	0.59	31.14
Wage (Housing)	1.29	2.12	63.49	3.60	0.00	0.00	0.00	0.02	3.07	7.87	18.54
Capacity Utilization Rate (Housing)	0.03	21.79	1.00	9.50	2.32	0.05	1.47	0.10	0.28	0.99	62.48

3.4.4 Shock Responses

In the last section, we analysed how well estimated model can replicate the business cycle observations. It is also important to understand what are the dynamics in the model implied by the shocks. In the section, we will focus on five of them that explained most the volatility in the model.[27]

Housing Demand Figure 3.5 plots impulse responses to the estimated housing demand shock. Overall, it raises on impact house prices and returns on housing investment. Since borrowers' collateral is linked to house prices, they can increase their level of borrowing and consumption. Given their higher marginal propensity to consume, the effects on total consumption is positive and entirely driven by borrowers, their consumption increase being high enough to compensate the decrease in lenders' consumption.

Housing demand shocks generate a co-movement between house prices, consumption, residential investment and hours worked (not shown) in both sectors of production observed in the data, especially during periods of housing booms. Shocks affect economic choices and, in particular, the housing and credit decisions of households. The occurrence of a positive housing demand shock prompts appreciations in housing prices and fuels current housing demand. Consequently, housing investment rises quickly on impact, with a peak increase of over 3 percent. House prices follow the same curve, with a peak increase of 2 percent on impact. Mortgage debt increases significantly, by more than 15 percent, reflecting the increase in housing investment but also the increase in house price that affect the value of all the undepreciated housing stock. This increase in the collateral value boosts the consumption of borrowers and causes inflationary pressures, which has for effect of increasing interest rates. Moreover, due to limits to credit, borrowers increase their labour supply in order to raise funds for housing investments. However, coupled with a decrease in non-residential investment, wages rise. The increase in consumption and housing investment makes also GDP rise. Thus, housing demand shocks in this model generate pro-cyclicality among relevant variables.

[27] See Appendix 3.2 for the other shock responses.

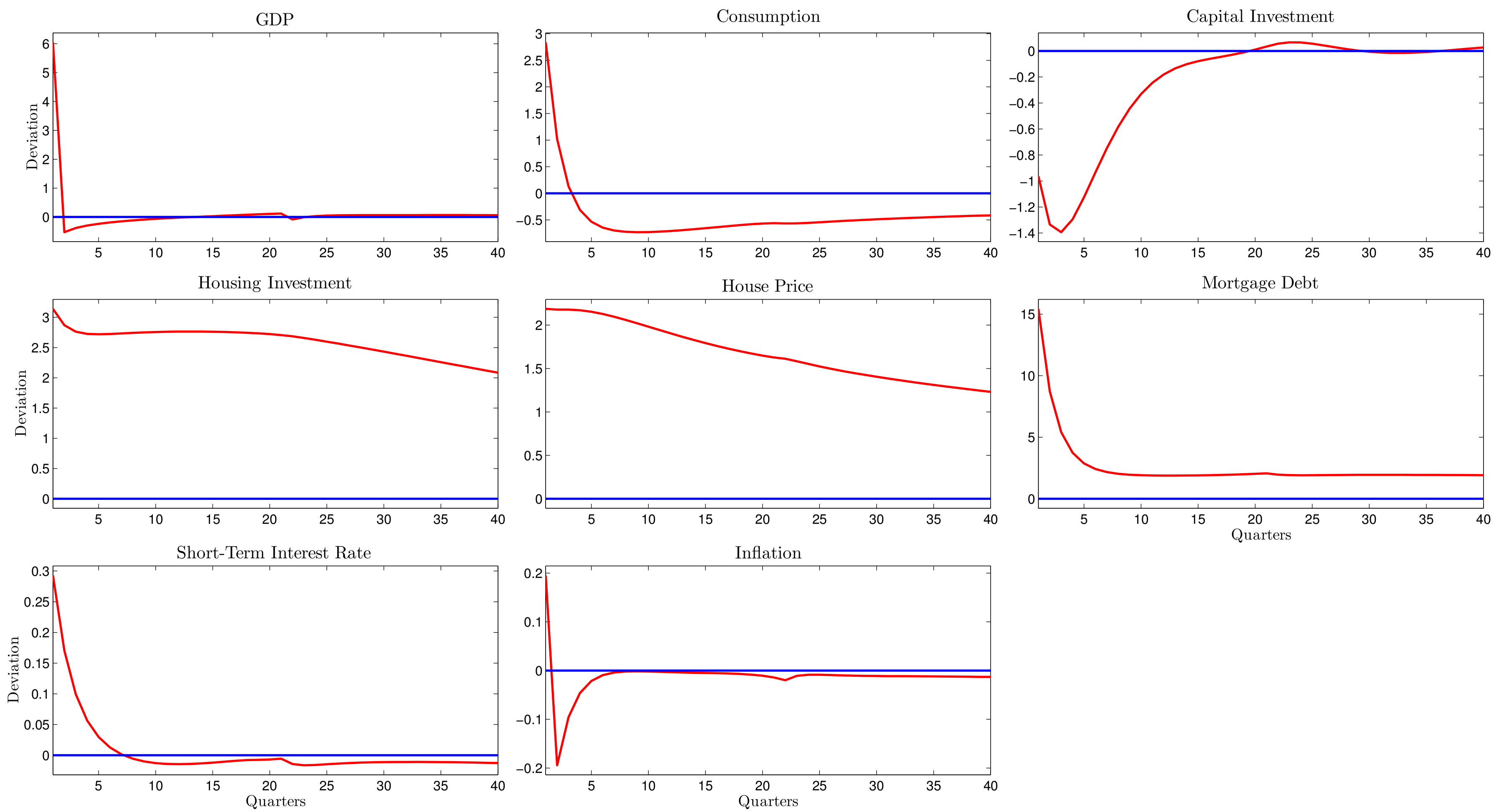


Figure 3.5: Shock Responses - Housing Demand Shock

Housing Technology Figure 3.7 presents the model's response to a one-standard deviation shock in housing technology. A positive technology shock in the housing sector leads to a rise in housing investment and a drop in housing prices due to the productivity gain. The negative net effect on the aggregate consumption masks two different realities. The positive shock in housing production technology induces an increase in real wage in both sectors, thus increasing labour income for both type of households. On the lenders side, this is translated in higher consumption and higher investments of all types (residential and non-residential in both sectors). On the borrowers side, this increase in labour income is not enough to compensate the decrease in house prices that translates into a decrease in the value of their collateral. This decrease in the value of the collateral, not compensated by the decrease in borrowing costs, has a negative impact on the level of consumption and mortgage debt. Finally, the persistence of the technology shock, cumulated with the persistence and the irreversibility of housing investment, maintains the real house prices lower than its steady-state value for a long period.

Labour Supply Figure 3.6 presents the model's response to a one-standard deviation shock in labour supply. This shock induces a greater disutility of hours worked to agents, causing an immediate decrease in hours worked in both sectors. This decrease leads to an increase in real wages in both sectors as the productivity increase slightly. Driving up the marginal cost of production, it is gradually transmitted to the inflation in the consumption sector, which drives interest rates up via the monetary policy response. The decrease in labour income and the increase in borrowing costs leads to a decrease in housing investment from the borrowers and a real house price decline, thereby reducing collateral values.

Monetary and Inflation Targeting Figure 3.8 plots the effects of monetary policy shocks. The temporary shock leads to a rise in the nominal and real short-term interest rates, a fall in output, consumption and residential and non-residential investment. In line with the stylised facts on monetary policy shocks, real wages fall (not shown). The largest effect on consumption is about 1.5 times the one on non-residential investment. Overall, these effects are consistent with the evidence found in the literature.

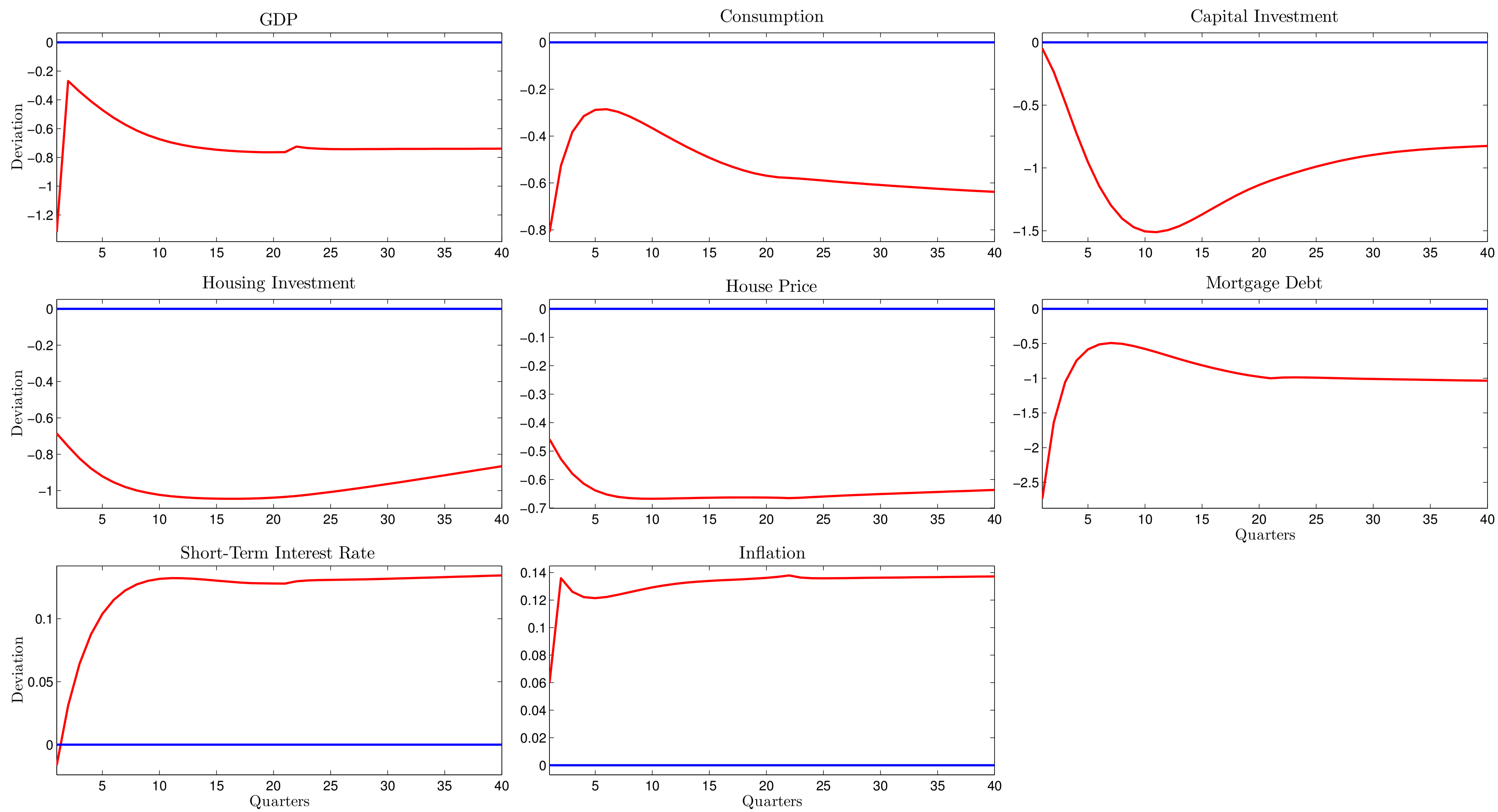


Figure 3.6: Shock Responses - Labour Supply Shock

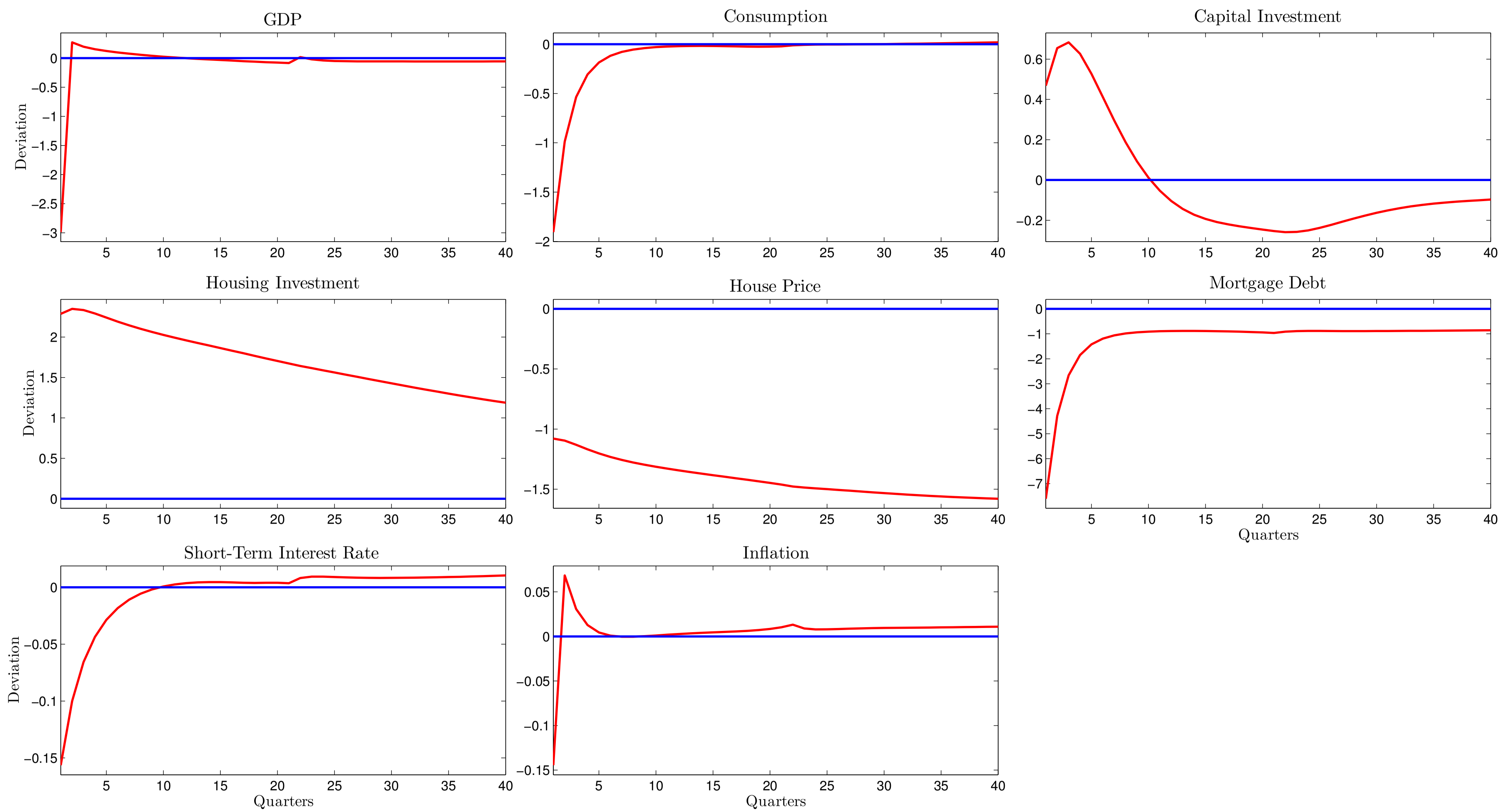


Figure 3.7: Shock Responses - TFP (Housing Sector) Shock

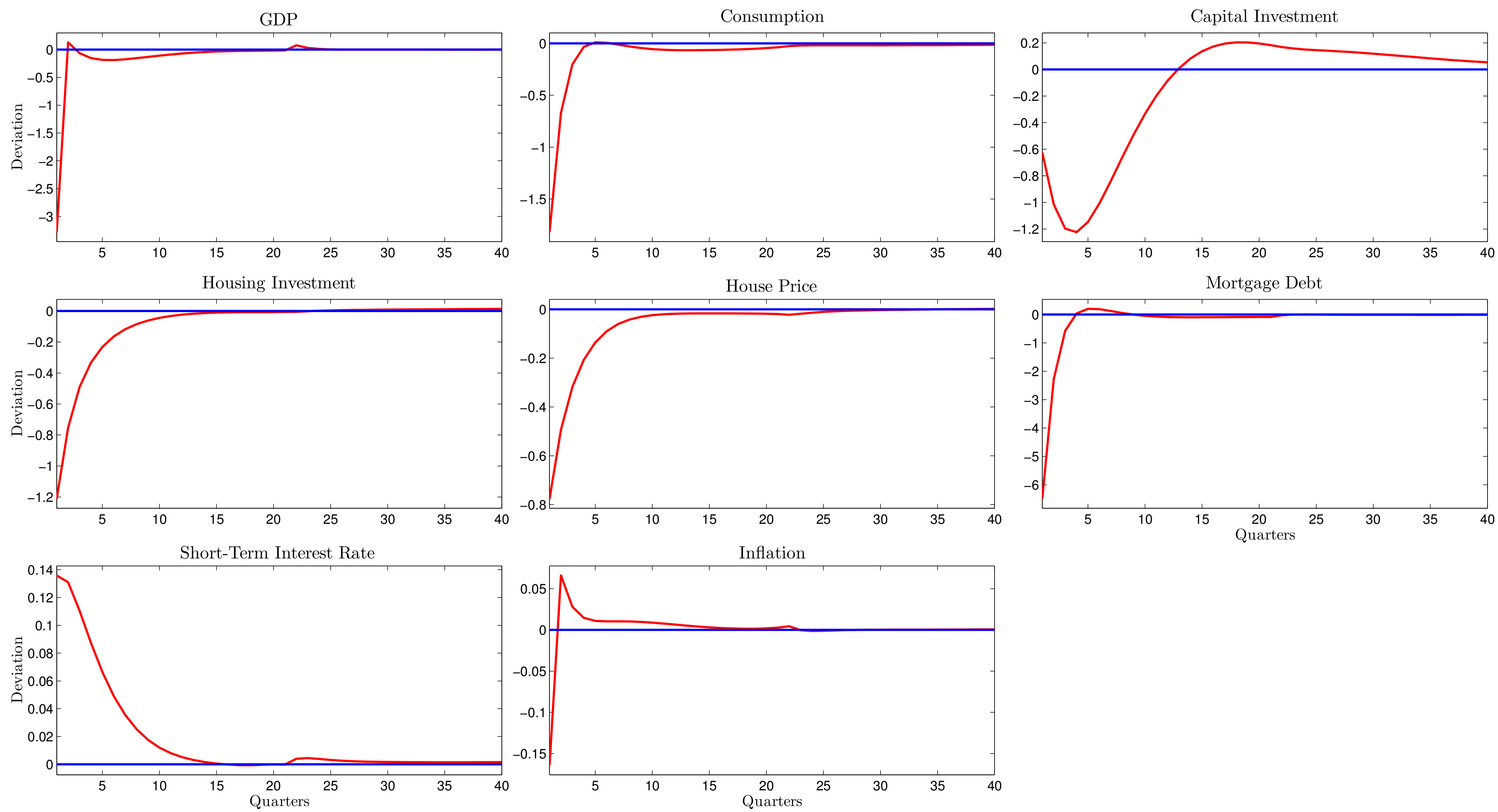


Figure 3.8: Shock Responses - Interest Rate Shock

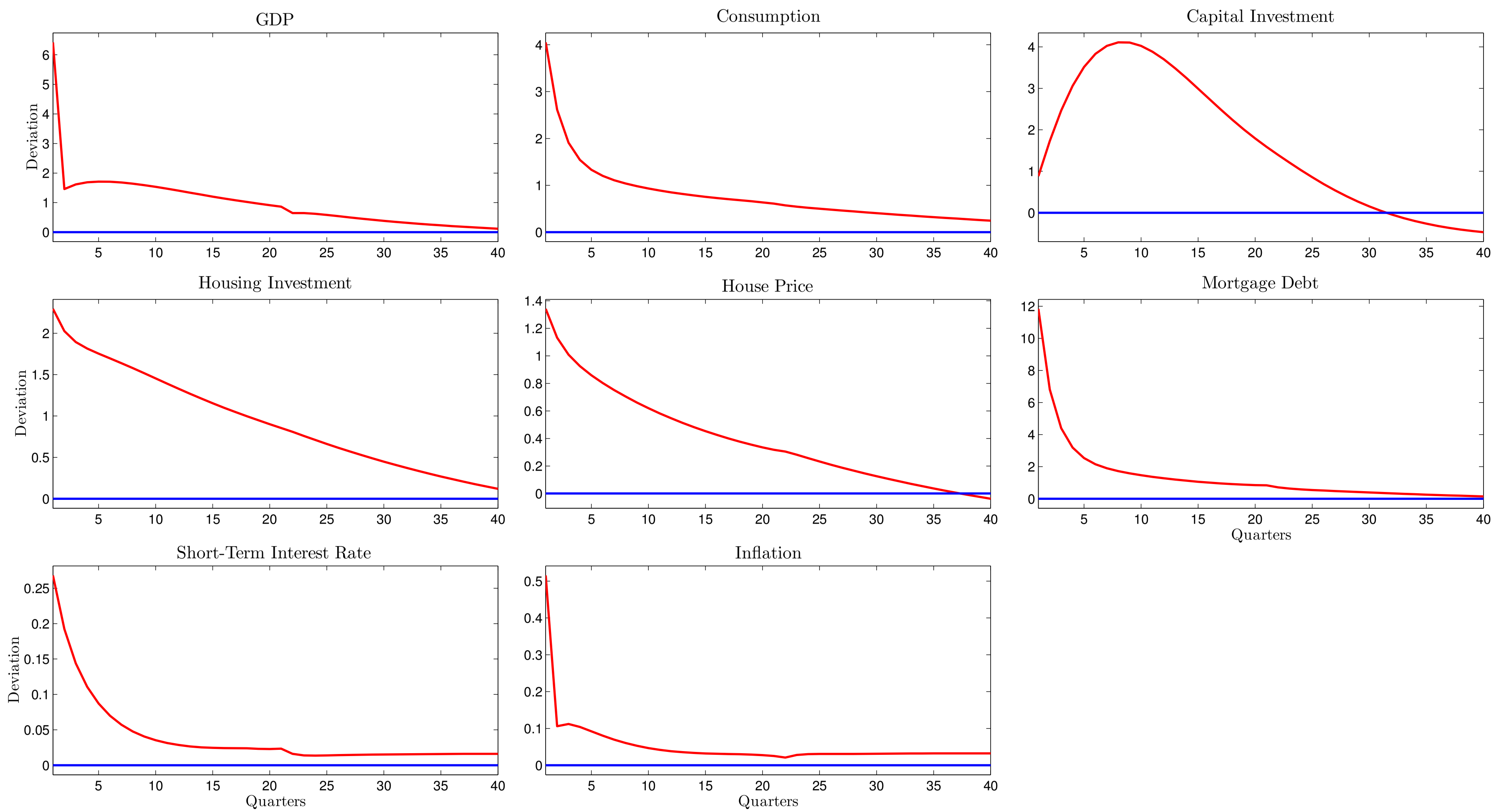


Figure 3.9: Shock Responses - Inflation Targeting Shock

Finally, Figure 3.9 presents the model's response following a one-standard deviation shock in inflation targeting. An increase in the inflation target means that, following an increase in inflation, the central bank will not increase the interest rate as much as in steady-state. The effects of a persistent change in the inflation objective are strikingly different from the monetary policy shock in one aspect. First, there is a liquidity effect, as nominal interest rates start increasing immediately as a result of the increased inflation expectations. Inflation picks up immediately, driven by an increase in consumption and housing investment. Interest rates continue to increase in response to higher inflation, this time at a lesser pace.

3.5 Housing Market Boom-Bust and Loan-to-Value Ratio

In this section, we first highlight key findings regarding the transmission mechanism of news shocks and describe the role of news shocks in housing market dynamics. We analyze by simulation the impact of news shocks on selected variables over the business cycle and show that news shocks can generate boom-bust housing market cycles. Then, we examine the effectiveness of implementing different countercyclical LTV ratios and compare it to the performance of a simple Taylor-type monetary policy rule augmented with house price inflation.

3.5.1 News Shocks and Housing Market Boom-Bust

It is well-known in the literature that rational-expectations DSGE models incorporating housing market and financial frictions can hardly generate boom-bust cycles. In general, macroeconomic models of housing markets mainly rely on fundamental developments in the economy to explain fluctuations in house prices and residential investment. However, survey evidence shows that house price dynamics are greatly related to macroeconomic expectations, especially to optimism about future house prices appreciations (Gomes and Mendicino, 2012). In our model, a natural way to incorporate expectations on housing prices is the exogenous process on housing demand.

Figure 3.10 presents, for key macroeconomic variables, the simulated impact of introducing anticipated shocks on housing demand within the model.[28] During this exercise, we assume that economic agents have in period t an information set Ω_t that goes beyond current and past realizations of ε^{ϵ^h}. The housing demand innovation $\varepsilon^{\epsilon^h}_{t-i}$, $\forall i$, is now composed of unanticipated and anticipated components:

$$\varepsilon^{\epsilon^h}_{t-i} = \sum_{j=0}^{s} \varepsilon^{\epsilon^h,j}_{t-i-j}.$$

In this formulation, agents observe the current and past values of the housing demand news shocks $\varepsilon^{\epsilon^h,j}$. The notation $\varepsilon^{\epsilon^h,j}_{t-i}$, $\forall i, j$, means that the anticipated disturbances (or news shocks) learnt in $t-i$ will affect the economy in j periods ahead (i.e. we learn in $t-i$ a news that will happen in $t-i+j$). More specifically, the disturbance $\varepsilon^{\epsilon^h,1}_t$ represents an innovation to ϵ^h_{t+1}, which is announced in period t but materializes only in period $t+1$. Note that $\varepsilon^{\epsilon^h,1}_t$ does not appear in the expression for $\varepsilon^{\epsilon^h}_t$ given above. Rather, the above expression features $\varepsilon^{\epsilon^h,1}_{t-1}$, the one-period-ahead announcement made in period $t-1$. Similarly, $\varepsilon^{\epsilon^h,2}_t$, $\varepsilon^{\epsilon^h,3}_t$ and $\varepsilon^{\epsilon^h,4}_t$ would be observed in t and represent two-, three-, and four-period-ahead announcements of future changes in the housing demand. In this set-up, $\varepsilon^{\epsilon^h,0}_t$ can be viewed as the usual contemporaneous (i.e. unanticipated) disturbances to ϵ^h_t.

Three simulations are presented in the Figure 3.10:

Case 1: Unanticipated shocks The baseline scenario is a series of four unanticipated shocks (i.e. $\varepsilon^{\epsilon^h,0}$) on housing demand. We assume an increasing value of $\varepsilon^{\epsilon^h,0}$ from $t+4$ to $t+7$:

- $\varepsilon^{\epsilon^h,0}_{t+4} = 0.5\sigma_{\epsilon^h}$
- $\varepsilon^{\epsilon^h,0}_{t+5} = 1.0\sigma_{\epsilon^h}$
- $\varepsilon^{\epsilon^h,0}_{t+6} = 1.5\sigma_{\epsilon^h}$
- $\varepsilon^{\epsilon^h,0}_{t+7} = 2.0\sigma_{\epsilon^h}$

[28] Based on the forward expansion available in IRIS Toolbox.

Case 2: Anticipated shocks with revision It consists of a series of four anticipated shocks learnt in t but unrealized (i.e. revised by an equivalent negative unanticipated shock in the period it was supposed to happen):

- $\varepsilon_t^{\epsilon^h,4} = 0.5\sigma_{\epsilon^h}$, but revised with $\varepsilon_{t+4}^{\epsilon^h,0} = -0.5\sigma_{\epsilon^h}$
- $\varepsilon_t^{\epsilon^h,5} = 1.0\sigma_{\epsilon^h}$, but revised with $\varepsilon_{t+5}^{\epsilon^h,0} = -1.0\sigma_{\epsilon^h}$
- $\varepsilon_t^{\epsilon^h,6} = 1.5\sigma_{\epsilon^h}$, but revised with $\varepsilon_{t+6}^{\epsilon^h,0} = -1.5\sigma_{\epsilon^h}$
- $\varepsilon_t^{\epsilon^h,7} = 2.0\sigma_{\epsilon^h}$, but revised with $\varepsilon_{t+7}^{\epsilon^h,0} = -2.0\sigma_{\epsilon^h}$

Case 3: Anticipated shocks with revision but no monetary policy reaction This case is the same as *Case 2*, but we exogenise the interest rate so it always stays at its steady-state value.

As expected, the unanticipated shocks plot on Figure 3.10 start to have an impact in $t+4$, when the shock happen. Therefore, the impacts under this scenario are the same as the impulse response following a housing demand shock described in Section 3.4. We observe a positive co-movement between housing investment, house price and consumption, but also a monetary policy reaction following the slight increase in inflation and the deviation of GDP from its steady-state value. Finally, housing demand increases following the four positive shocks from $t+4$ to $t+7$, and stays nearly flat afterward given that the persistence parameter is closed to 1.

The story is different for the anticipated shock scenario. News shocks generate co-movement between house prices, consumption and residential investment, but also hours worked (not shown) in both sectors of production observed in the data, especially during periods of housing booms. News shocks affect economic choices and, in particular, the housing and credit decisions of households differently than unanticipated shocks. Expectations about the occurrence of positive housing demand shocks immediately generate beliefs of future appreciations in housing prices and fuel current housing demand. All the agents learn about the positive news shocks at the same moment, in $t + 1$, in contrast with the unanticipated shock case, where the information was slowly diffused over four periods. Consequently, housing investment rise quickly on impact, with a peak increase of near 11 percent in $t+4$. House prices follow the same curve, with a peak increase of 9 percent in $t+4$. Mortgage debt increases significantly, by more than 60 percent, reflecting the increase in housing investment, but also the increase in house prices that affect the value of all the undepreciated housing stock. This increase in the collateral value boosts the consumption of borrowers and fuels inflation, inducing a rise in interest rates. Overall, as news spread, the value of housing collateral increases and the rise in house prices is, thus, coupled with an expansion in household's credit and consumption. Moreover, due to limits to credit, borrowers increase their labour supply in order to raise internal funds for housing investments. For the decrease in non-residential investment to be coupled with an increase in hours, wages rise. The increase in consumption and housing investment also causes GDP to rise. Thus, news shocks in this model generate pro-cyclicality among relevant variables. However, in $t+4$, agents learn about the housing demand and revise their views on the current state of the economy: positive housing demand shock has not occur. Housing investment and house prices start to decline on impact, followed by mortgage debt. The collateral value then starts to drop and agents have to revise their consumption level. The same mechanism occurs every time when the positive housing demand news shock does not materialize. In $t+8$, housing investment declines by 12 percent and house prices by 9 percent. Moreover, from peak to through, consumption level decline by near 25 percent, and the real GDP decline by close to 10 percent, generating a recession. During that period, housing demand never moves. All of this resulted only from unrealized expectations.

Finally, the last case uses the same path of news and unanticipated shocks, but exogenises the interest rate and makes it non-reactive to changes in the economic state. The resulting dynamic is the same as in for anticipated shocks with monetary policy reaction, but with stronger macroeconomic variables reactions due to the non-reaction of interest rates to inflation and GDP increases.

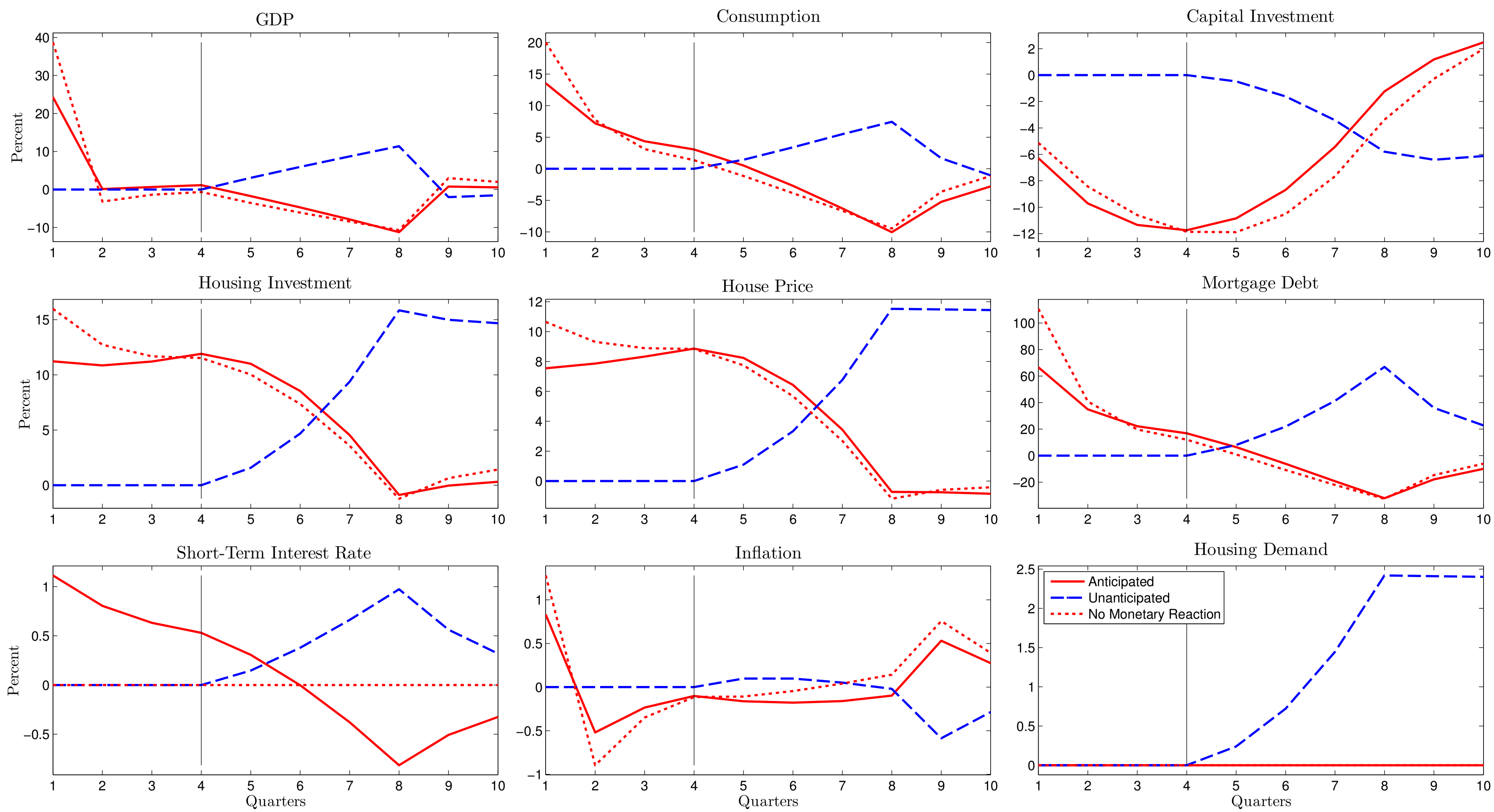


Figure 3.10: ANTICIPATED AND UNANTICIPATED HOUSING DEMAND SHOCK

Overall, the three case scenarios suggests that news shocks could play an important role in boom-bust housing market cycles as they can generate co-movement between consumption, housing investment and house prices, similar to what is observed in the data, especially during periods of housing booms. News shocks contribute to the boom- and bust-phases in house prices.

3.5.2 Countercyclical Loan-to-Value Ratio

We now study the effectiveness of implementing a countercyclical LTV ratio to reduce or eliminate the amplitude of the boom-bust cycle describes above (i.e. *Case 2*, anticipated shocks). First, we consider two countercyclical LTV ratios. In both cases, we assume that the monetary policy authority continues to follow the estimated Taylor-type rule and we allow the LTV ratio to vary around its long-run setting of 85 percent. The first rule considered is based on the deviation of house prices from their steady-state

$$\omega_t = \omega_{ss} \left(\frac{q_t^h}{q^h} \right)^{\phi^\omega},$$

while the second rule is based on the deviation of the debt-to-GDP ratio from its steady-state

$$\omega_t = \omega_{ss} \left(\frac{M_t/y_t}{M/y} \right)^{\phi^\omega},$$

with ϕ^ω being the countercyclical parameter.[29] Finally, we compare the results of these regulatory LTV policies with the performance of a Taylor-type monetary policy rule augmented with house prices inflation

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}} \right)^{\rho_r} \left(\frac{\pi_t^c}{\epsilon_t^{\pi^c}} \right)^{(1-\rho_r)\rho_{\pi^c}} \left(\frac{Y_t}{Y_{ss}} \right)^{(1-\rho_r)\rho_y} \left(\frac{\pi_t^h}{\pi^h} \right)^{(1-\rho_r)\rho_{\pi^h}} \exp\left(\varepsilon_t^R \right).$$

Figures 3.11, 3.12 and 3.13 show the simulation results. We implemented three cases of macroprudential policy. For both rules the countercyclical LTV, we implemented the rules

[29] This choice of tested policies is based on the literature but remains arbitrary. Many other rules for countercyclical LTV could be tested, but a full comparative study based on welfare criterion would be necessary. This study can serve as a starting point to welfare studies.

with $\phi^{\omega} = \{0.0, 0.5, 1.0\}$, the case with the countercyclical parameter equal to 0 replicating *Case 2* (not countercyclical LTV) to facilitate comparisons. In the case of monetary policy, three value of the parameters are considered, namely $\rho_{\pi^h} = \{0.0, 1.0, 2.0\}$, the case with the house price inflation parameter equal to 0 replicating *Case 2* (not countercyclical LTV) to facilitate comparisons. When policy is based on house prices, for both parameters values the countercyclical LTV ratio does not reduce the surge in housing investment and house prices. Expectations about the occurrence of positive housing demand shocks still immediately generate beliefs of future appreciations in housing prices and fuel current housing demand. However, the transmission mechanism creating a spillover effect on consumption via loosening of the collateral constraint is greatly reduced when $\phi^{\omega} = 0.5$ and eliminated when $\phi^{\omega} = 1.0$. Therefore, we still experience a house price correction of near 10 percent and a housing investment decrease of 12 percent when agents realize that the expectations do not materialize, but this does not lead to a recession. When policy is based on the debt-to-GDP ratio, as in the previous rule studied, house prices and housing investment are not affected by LTV, because the housing demand news shocks dominates, but the transmission mechanism is greatly reduced. However, when $\phi^{\omega} = 1.0$, the wealth effect vis the collateral constraint is still materialize and we still observe a decline in consumption.

Finally, we consider a modified Taylor-type rule augmented with house price inflation. As expected, the effects of including the house price inflation in the monetary policy rule are more diffuse and affect all the macroeconomic variables. It helps reducing the house prices and housing investment impacts of news shocks on housing demand; however, it is less effective than a sectoral policy like the LTV ratio to target uniquely the spillover of the wealth effect on consumption via the loosening of the collateral constraint.

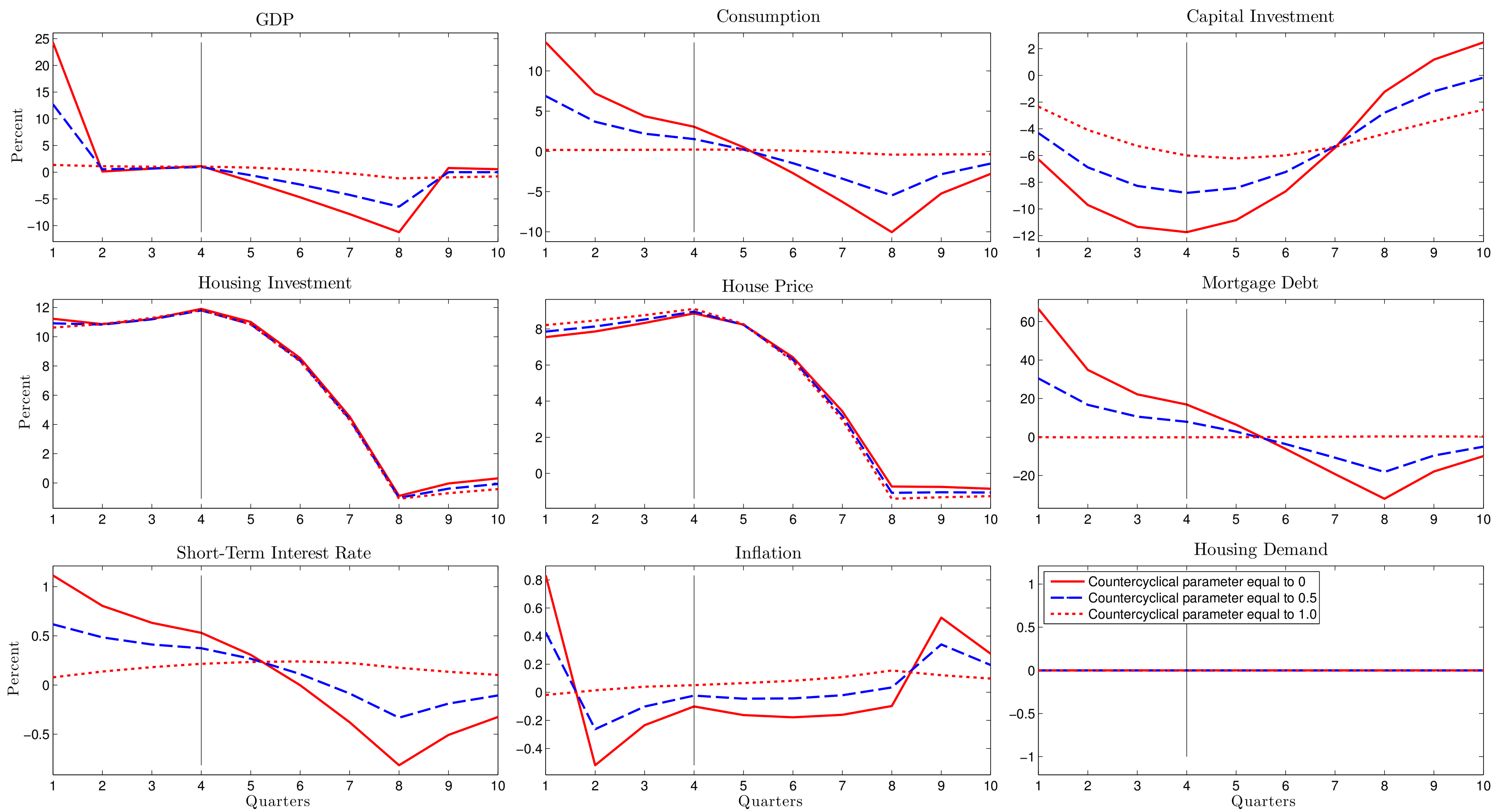


Figure 3.11: Countercyclical LTV Policy based on House Price

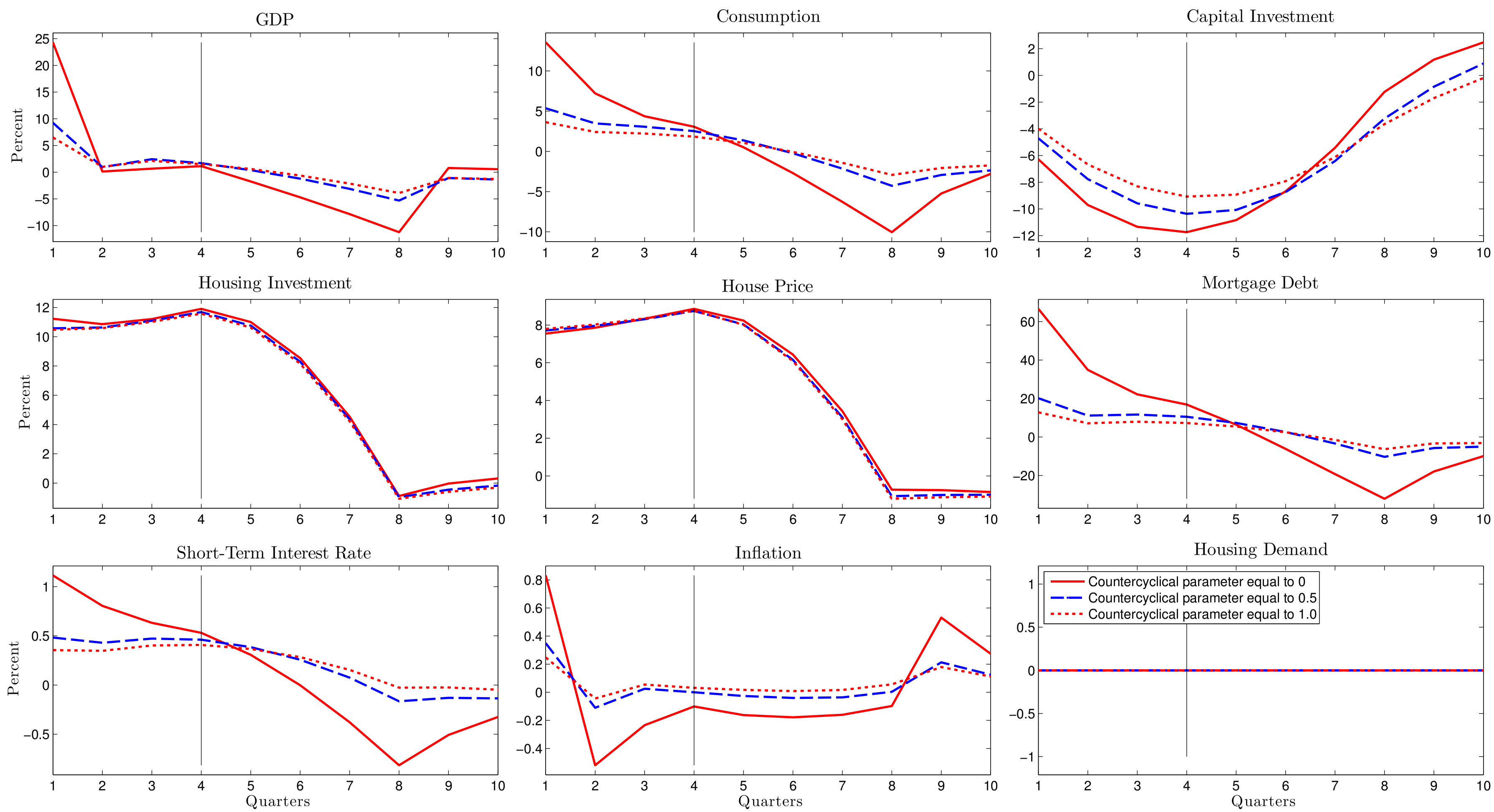


Figure 3.12: COUNTERCYCLICAL LTV POLICY BASED ON DEBT-TO-GDP RATIO

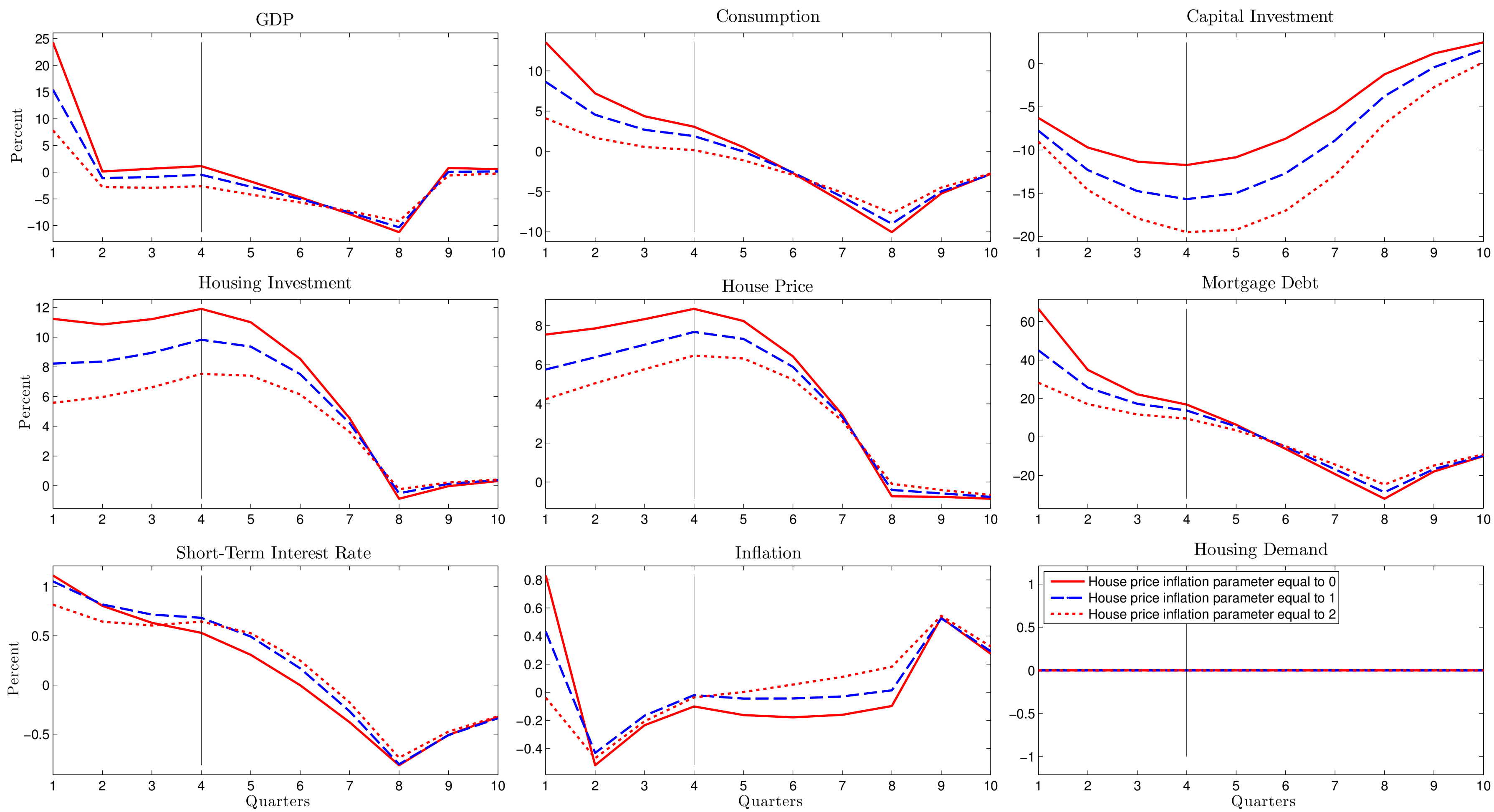


Figure 3.13: Monetary Policy Responsive to House Price Inflation

3.6 Conclusion

The objective of this chapter was twofold. We wanted to study if there is any statistical evidence suggesting an important collateral link between the housing market and the rest of the economy, and, if such a link exists, to determine whether it is mostly demand- or supply-driven. We also followed the *news shocks* literature and looked if a housing-market boom-bust cycle can arise endogenously following unrealized expectations of a rise in housing demand. To this end, we constructed a New Keynesian model in which a fraction of households borrow against the value of their houses. We estimated the model with Canadian data using Bayesian methods and assessed the model's ability to capture key features of consumption and house price data. Finally, we performed an analysis to determine how well the introduction of a countercyclical loan-to-value (LTV) ratio can reduce household indebtedness and housing price fluctuations compared to a monetary policy rule augmented with house price inflation.

We find statistical evidence suggesting an important collateral link between the housing market and the rest of the economy, and this link is mainly driven by demand factors. We also find that the introduction of news shocks can generate a housing market boom-bust cycle, the bust following unrealized expectations on housing demand. Our estimated model explains several features of the data. At the cyclical frequencies, it matches the observation that both housing prices and housing investments are strongly procyclical with consumption (and then with GDP), volatile and sensitive to interest rates.

Our study also suggests that higher loan-to-value ratios can amplify housing-market boom-bust cycles by encouraging speculative housing investments by credit-constrained borrowers, but the amplification effect is mainly concentrated via the collateral constraints. However, our study suggests that, in line with preceding dynamic equilibrium models with credit-constrained borrowers considered by Iacoviello (2005) and Kiyotaki et al. (2010), the loan-to-value ratio does not significantly alter aggregate house-price dynamics, but it is a viable tool to mitigate the spillover effects via the collateral constraint.

As pointed out in Iacoviello and Neri (2010), a good part of the fluctuations in housing prices and housing investment observed in the data are viewed by the model as the outcome of the exogenous shift in housing demand. This shock potentially includes unmodeled features of the model. The housing investment is mainly made at the household level, while our data are per capita. With the constant decrease in the number of persons per household observed since the beginning the 70s, this dynamics is probably capture within the housing demand shock. Also, using perturbation methods, it is hard to model exogenous change in policy, as the one we observed in regulatory LTV ratios over the last 15 years. Changes in LTV requirements could potentially have been captured in the housing demand shock. These elements are interesting questions for further research.

Conclusion générale

Cette thèse est composée de trois essais sur les fluctuations macroéconomiques et les cycles économiques. Le premier chapitre s'intéresse aux anticipations sur la politique monétaire et sur la réaction des agents écononomiques face à ces anticipations. Une emphase particulière a été mise sur la consommation de biens durables et l'endettement relié à ce type de consommation. Le deuxième chapitre aborde la question de l'influence des variations du taux de change sur la demande de travail dans le secteur manufacturier canadien. Finalement, le troisième chapitre s'intéresse aux retombées économiques, parfois négatives, du marché immobilier sur la consommation des ménages et aux répercussions sur le prix des actifs immobiliers et sur l'endettement des ménages d'anticipations sur la demande dans le marché immobilier.

L'objectif principal du premier chapitre était de distinguer les effets des chocs de politique monétaire non-anticipés et anticipés sur la consommation de biens durables. Des recherches appronfondies ont été menées sur les effets des chocs non-anticipés sur les dépenses en biens durables, tandis que les effets des chocs anticipés étaient restés essentiellement inexploré. Étant donné l'importance de cette questions pour la mise en oeuvre de la politique monétaire, nous avons effectué une analyse empirique et théorique de cette question.

Dans notre étude, l'analyse empirique est devenu possible grâce à notre approche proposée pour récupérer les chocs anticipés. Nous avons proposé et mis en oeuvre une approche simple pour l'identification des chocs anticipés au sujet de la politique monétaire future, où les chocs sont identifiés de manière récursive à partir des résidus d'une règle de politique monétaire estimée en utilisant des données d'enquête multi-horizon. Nous avons ensuite utilisé ces chocs anticipés estimés dans un ARVS et trouvé qu'un resserrement de la politique monétaire attendue conduit à une augmentation de la production, de la consommation de biens non-durables et durables, et du prix réel des biens durables. Même si les chocs anticipés sont responsables d'une part significative des fluctuations de la production et de la consommation, ils contribuent moins ques les chocs non-anticipés aux fluctuations économiques. Notre analyse théorique, basé sur un modèle EGDS avec des biens durables et des rigidités nominales, a montré que ce modèle avec une rigidité du prix des biens durables peut causer un co-mouvement de la consommation des biens non-durables et durables en réponse à un choc anticipés de politique monétaire, corroborant ainsi les résultats trouvés de manière empirique avec le ARVS.

En conclusion, cette étude met en évidence des résultats intéressants sur le lien entre les chocs monétaires anticipés, la consommation de biens non-durables et durables, et les facteurs macroéconomiques structurels. Toutefois, elle est limitée dans le sens où elle est muette sur la manière dont les chocs anticipés se forment. Des extensions possibles de ce travail comprendraient notamment une interprétation structurelle potentielle des chocs anticipés. Ils sont potentiellement liées aux annonces de la Réserve fédérale, ou aux nouvelles économiques en général, comme la publications des indicateurs macroéconomiques. Les recherches futures devraient explorer cette possibilité. De plus, les chocs anticipés inclus dans notre modèle sont considérés comme non-corrélés contemporainement ainsi qu'à toutes la valeurs avancées ou retardées. Cette hypothèse est relativement forte. Les études futures pourraient explorer des corrélations possibles entre les chocs anticipés. Enfin, une autre question intéressante est d'évaluer si une règle de politique monétaire intégrant des chocs anticipés pourrait être statistiquement équivalente à une règle variant dans le temps en fonction d'un processus Markovien ou des paramètres variant dans le temps. En effet, la mise en oeuvre d'une règle invariable dans le temps avec des nouvelles chocs permet aux autorités monétaires de se écarter systématiquement de la règle pendant une certaine période de temps sans affecter les paramètres de réaction.

Le second chapitre abordait la question de l'influence des variations du taux de change sur la demande de travail dans le secteur manufacturier canadien. Nous avons démontré que les cycles d'expansion et de ralentissement observés dans le marché du travail des industries manufacturières canadienne au cours des dernières décennies sont fortement liés aux fluctuations du taux de change du dollar canadien. Notre stratégie économétrique utilise des techniques d'estimation de données de panel et nous contrôlons pour la présence de racines unitaires, de cointégration ainsi que de dépendance transversale trouvés dans les données. Nos résultats suggèrent qu'une appréciation de 10 pourcent du dollar canadien peut diminuer les heures travaillées et les emplois de 3 pourcent et que cet effet se produit relativement lentement, avec environ 13 pourcent de l'écart entre le niveau de travail réel et ciblé comblé à chaque année. Nous constatons aussi que le PIB des partenaires commerciaux du Canada a des effets importants sur les emplois du secteur manufacturier canadiens. Ces résultats sont plus importants dans les industries ayant une exposition commerciale nette supérieure à la moyenne et nous trouvons que la promulgation des deux grands accords commerciaux en 1989 et 1994 a eu des effets négatifs importants sur le nombre d'heures travaillées et les emplois dans les industries manufacturières canadiennes. Ces résultats sont d'actualité, étant donné que la récente dépréciation du dollar canadien a ravivé l'intérêt sur l'évolution future des industries manufacturières canadiennes.

Le but du troisième chapitre avait deux volets. D'une part, nous voulions étudier l'importance de la relation entre les hausses du prix des maisons et les hausses de dépenses qui s'effectue grâce à une amélioration de la capacité d'emprunt des ménages. Plus spécifiquement, nous tentons de déterminer si cette relation entre le marché immobilier et le reste de l'économie est statistiquement significative et, si c'est le cas, est ce que c'est dû à l'offre ou à la demande. Nous avons également suivi la littérature portant sur les chocs anticipés et avons tenté de déterminer si des cycle d'expansion et de récession peuvent être produits de façon endogène suite à une augmentation de la demande de maisons. Pour ce faire, nous avons élaboré un modèle néo-keynésien dans lequel une fraction des ménages emprunte en mettant en garantie leur maison. Nous estimons ce modèle à l'aide de données canadiennes par des méthodes Bayesiennes. Par la suite, nous avons tenté de déterminer à quel point l'instauration d'un ratio prêt-à-la-valeur contracyclique est efficace pour réduire l'endettement des ménages et les fluctuations des prix des maisons par rapport à une règle de politique monétaire répondant à l'inflation du prix des maisons.

Notre analyse empirique révèle qu'il existe une relation importante entre l'appréciation des prix des maisons et le reste de l'économie et que cette dynamique est principalement dû à des facteurs de demande. Nous trouvons également que l'ajout de chocs anticipés peut générer un cycle d'expansion et de récession dans le marché des maisons, la récession survenant après que des attentes se soient avérées infondées. Notre modèle estimé explique plusieurs caractéristiques des données. Aux fréquences cycliques, il fait correspondre les observations voulant que le prix des maisons et l'investissement résidentiel réagissent de manière fortement procycliques avec la consommation (et donc avec le PIB), qu'ils soient volatiles et sensibles aux taux d'intérêt.

Notre étude révèle que des RPV plus élevés peuvent amplifier les cycles d'expansion et récession en favorisant les investissements immobiliers spéculatifs des emprunteurs dont le crédit est limité et que cet effet est surtout dû la valeur des propriétés mises en garantie. Toutefois, le RPV ne semble pas avoir d'impact significatif sur les dynamiques agrégées du prix des maisons, ce qui est conforme à d'autres modèles EGDS avec contrainte de crédit pour les emprunteurs élaborés par Iacoviello (2005) et Kiyotaki et al. (2010).

Une portion significative des fluctuations du prix des maisons et de l'investissement résidentiel observées dans les données sont considérées par le modèle comme le résultat du changement exogène de la demande de maison. Ce choc inclut potentiellement plusieurs caractéristiques non-modélisées. L'investissement dans le logement est principalement fait au niveau des ménages, tandis que nos données sont par habitant. Avec la diminution constante du nombre de personnes par ménage observée depuis le début des années 70, cette dynamique est probablement capté dans le choc de la demande de logements. De plus, en utilisant la méthode des perturbations, il est difficile de modéliser des changements non-linéaires et discrets de politiques, comme ceux que nous avons observé concernant le ratio réglementaire de prêt-à-la-valeur au cours des 15 dernières années. Les changements dans les exigences du prêt-à-la-valeur pourraient avoir été pris en compte dans le choc de la demande de logements. Ce sont des questions intéressantes pour de futures recherches.

Bibliographie

Adolfson, M., S. Laseen, J. Linde, and M. Villani (2007, July). Bayesian estimation of an open economy dsge model with incomplete pass-through. *Journal of International Economics 72*(2), 481–511.

Ahn, S. K. and G. C. Reinsel (1990). Estimation for partially nonstationary multivariate autoregressive models. *Journal of the American Statistical Association 85*(411), pp. 813–823.

Alpanda, S., G. Cateau, and C. Meh (2014). A policy model to analyze macroprudential regulations and monetary policy. Working Papers 14-6, Bank of Canada.

Alpanda, S. and S. Zubairy (2014). Addressing household indebtedness : Monetary, fiscal or macroprudential policy ? Working Papers 14-58, Bank of Canada.

An, S. and F. Schorfheide (2007). Bayesian analysis of dsge models. *Econometric Reviews 26*(2-4), 113–172.

Andrews, D. W. K. (1993, July). Tests for parameter instability and structural change with unknown change point. *Econometrica 61*(4), 821–56.

Andrle, M. and J. Benes (2013, December). System priors : Formulating priors about dsge models' properties. IMF Working Papers 13/257, International Monetary Fund.

Auray, S., P. Gomme, and S. Guo (2009, July). Nominal rigidities, monetary policy and pigou cycles. Working Papers 09005, Concordia University, Department of Economics.

Bai, J. and S. Ng (2004, 07). A PANIC attack on unit roots and cointegration. *Econometrica 72*(4), 1127–1177.

Baltagi, B. H. and C. Kao (2000, March). Nonstationary panels, cointegration in panels and dynamic panels : A survey. Center for Policy Research Working Papers 16, Center for Policy Research, Maxwell School, Syracuse University.

Banerjee, A., M. Marcellino, and C. Osbat (2004, December). Some cautions on the use of panel methods for integrated series of macroeconomic data. *Econometrics Journal 7*(2), 322–340.

Barsky, R. B., C. L. House, and M. S. Kimball (2007, June). Sticky-price models and durable goods. *American Economic Review 97*(3), 984–998.

Beaudry, P. and F. Portier (2004, September). An exploration into pigou's theory of cycles. *Journal of Monetary Economics 51*(6), 1183–1216.

Beaulieu, E. (2000, May). The Canada-US free trade agreement and labour market adjustment in Canada. *Canadian Journal of Economics 33*(2), 540–563.

Blanchard, O. J. and C. M. Kahn (1980, July). The solution of linear difference models under rational expectations. *Econometrica 48*(5), 1305–11.

Breitung, J. (2005). A parametric approach to the estimation of cointegration vectors in panel data. *Econometric Reviews 24*(2), 151–173.

Bruneau, G. (2015). Bootstrap fisher-johansen panel cointegration test.

Bruneau, G. and K. Moran (2012, July). Exchange rate fluctuations and labour market adjustments in Canadian manufacturing industries. Working Paper 12-27, CIRPÉE.

Burgess, S. M. and M. M. Knetter (1998, February). An international comparison of employment adjustment to exchange rate fluctuations. *Review of International Economics 6*(1), 151–63.

Calvo, G. A. (1983, September). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics 12*(3), 383–398.

Campa, J. M. and L. S. Goldberg (2001, August). Employment versus wage adjustment and the U.S. dollar. *The Review of Economics and Statistics 83*(3), 477–489.

Campbell, J. Y. (2013). Mortgage market design. *Review of Finance 17*(1), 1–33.

Cerrato, M. and N. Sarantis (2007). A bootstrap panel unit root test under cross-sectional dependence, with an application to PPP. *Computational Statistics & Data Analysis 51*(8), 4028 – 4037.

Chang, Y. (2004, June). Bootstrap unit root tests in panels with cross-sectional dependency. *Journal of Econometrics 120*(2), 263–293.

Choi, I. (2001, April). Unit root tests for panel data. *Journal of International Money and Finance 20*(2), 249–272.

Choi, I. (2002). Combination unit root tests for cross-sectionally correlated panels. Working papers, Hong Kong University of Science and Technology.

Christensen, I., P. Corrigan, C. Mendicino, and S.-I. Nishiyama (2009). Consumption, housing collateral, and the canadian business cycle. Working Papers 09-26, Bank of Canada.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (1999, October). Monetary policy shocks : What have we learned and to what end ? In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume 1 of *Handbook of Macroeconomics*, Chapter 2, pp. 65–148. Elsevier.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005, February). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy 113*(1), 1–45.

Christiano, L. J. and T. J. Fitzgerald (2003, 05). The band pass filter. *International Economic Review 44*(2), 435–465.

DeJong, D. N., B. F. Ingram, and C. H. Whiteman (2000, October). A bayesian approach to dynamic macroeconomics. *Journal of Econometrics 98*(2), 203–223.

Dekle, R. (1998, October). The yen and japanese manufacturing employment. *Journal of International Money and Finance 17*(5), 785–801.

Del Negro, M., F. Schorfheide, F. Smets, and R. Wouters (2007, April). On the fit of new keynesian models. *Journal of Business & Economic Statistics 25*, 123–143.

Di Iorio, F. and S. Fachin (2009). A residual-based bootstrap test for panel cointegration. *Economics Bulletin 29*(4), 3222–3232.

Dion, R. (2000). Trends in Canada's merchandise trade. *Bank of Canada Review 2000*(Winter), 29–41.

Dorich, J., M. K. Johnston, R. R. Mendes, S. Murchison, and Y. Zhang (2013). Totem ii : An updated version of the bank of canada's quarterly projection model. Technical Reports 100, Bank of Canada.

Driscoll, J. C. and A. C. Kraay (1998, November). Consistent covariance matrix estimation with spatially dependent panel data. *The Review of Economics and Statistics 80*(4), 549–560.

Eberhardt, M. and F. Teal (2011, 02). Econometrics for grumblers : A new look at the literature on cross-country growth empirics. *Journal of Economic Surveys 25*(1), 109–155.

Engle, R. F., , and B. S. Yoo (1991). *Advances in Econometrics : Co-Integration, Spurious Regression, and Unit Roots*, Chapter Cointegrated economic time series : an overview with new results, pp. 237–266. JAI Press.

Erceg, C. and A. Levin (2006, October). Optimal monetary policy with durable consumption goods. *Journal of Monetary Economics 53*(7), 1341–1359.

Evans, M. and P. Wachtel (1993, Aug.). Inflation regimes and the sources of inflation uncertainty. *Journal of Money, Credit and Banking 25*(3), 475–511.

Fachin, S. (2007). Long-run trends in internal migrations in italy : a study in panel cointegration with dependent units. *Journal of Applied Econometrics 22*(2), 401–428.

Fisher, R. A. (1932). *Statistical Methods for Research Workers* (4th ed.). Edinburgh : Oliver & Boyd.

Gaston, N. and D. Trefler (1997, February). The labour market consequences of the canada-u.s. free trade agreement. *Canadian Journal of Economics 30*(1), 18–41.

Gelain, P., M. Kolasa, and M. Brzoza-Brzezina (2014). Monetary and macroprudential policy with multi-period loans. 2014 Meeting Papers 575, Society for Economic Dynamics.

Gelain, P., K. J. Lansing, and C. Mendicino (2013, June). House prices, credit growth, and excess volatility : Implications for monetary and macroprudential policy. *International Journal of Central Banking 9*(2), 219–276.

Gengenbach, C., F. Palm, and J.-P. Urbain (2010). Panel unit root tests in the presence of cross-sectional dependencies : Comparison and implications for modelling. *Econometric Reviews 29*(2), 111–145.

Gomes, S. and C. Mendicino (2011). Housing market dynamics : Any news ? Technical report.

Gomes, S. and C. Mendicino (2012, July). Housing market dynamics : Any news ? Working Papers Department of Economics 2012/23, ISEG - School of Economics and Management, Department of Economics, University of Lisbon.

Gomme, P. and P. Rupert (2007, March). Theory, measurement and calibration of macroeconomic models. *Journal of Monetary Economics 54*(2), 460–497.

Groen, J. J. J. and F. Kleibergen (2003, April). Likelihood-based cointegration analysis in panels of vector error-correction models. *Journal of Business & Economic Statistics 21*(2), 295–318.

Hadri, K. (2000). Testing for stationarity in heterogeneous panel data. *Econometrics Journal 3*(2), 148–161.

Hamermesh, D. S. and G. A. Pfann (1996, September). Adjustment costs in factor demand. *Journal of Economic Literature 34*(3), 1264–1292.

Hamilton, J. (1994). *Time Series Analysis.* Princeton : Princeton University Press.

Hansen, B. E. (1997, January). Approximate asymptotic p values for structural-change tests. *Journal of Business & Economic Statistics 15*(1), 60–67.

Harris, R. D. F. and E. Tzavalis (1999, August). Inference for unit roots in dynamic panels where the time dimension is fixed. *Journal of Econometrics 91*(2), 201–226.

Horvath, M. (2000, February). Sectoral shocks and aggregate fluctuations. *Journal of Monetary Economics 45*(1), 69–106.

Iacoviello, M. (2005, June). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review 95*(3), 739–764.

Iacoviello, M. and S. Neri (2010, April). Housing market spillovers : Evidence from an estimated dsge model. *American Economic Journal : Macroeconomics 2*(2), 125–64.

Im, K. S., M. H. Pesaran, and Y. Shin (2003, July). Testing for unit roots in heterogeneous panels. *Journal of Econometrics 115*(1), 53–74.

IMF (2012). Chapter 3 dealing with household debt.

IMF (2013). Key aspects of macroprudential policy.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control 12*(2-3), 231–254.

Johansen, S. (1991, November). Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica 59*(6), 1551–80.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2010, March). Investment shocks and business cycles. *Journal of Monetary Economics 57*(2), 132–145.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2013, April). Household leveraging and deleveraging. NBER Working Papers 18941, National Bureau of Economic Research, Inc.

Kannan, P., P. Rabanal, and A. M. Scott (2012, June). Monetary and macroprudential policy rules in a model with house price booms. *The B.E. Journal of Macroeconomics 12*(1), 1–44.

Kao, C. (1999, May). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics 90*(1), 1–44.

Kao, C. and B. Chen (1995). On the estimation and inference for cointegration in panel data when the cross section and time series dimensions are comparable. Manuscript, Center for Policy Research.

Kao, C. and M.-H. Chiang (1999, March). On the estimation and inference of a cointegrated regression in panel data. Center for Policy Research Working Papers 2, Center for Policy Research, Maxwell School, Syracuse University.

Kilian, L. (1998, May). Small-sample confidence intervals for impulse response functions. *The Review of Economics and Statistics 80*(2), 218–230.

Kiyotaki, N., A. Michaelides, and K. Nikolov (2010, July). Winners and Losers in House Markets. Working Papers 2010-5, Central Bank of Cyprus.

Kiyotaki, N. and J. Moore (1997, April). Credit cycles. *Journal of Political Economy 105*(2), 211–48.

Klein, P. (2000, September). Using the generalized schur form to solve a multivariate linear rational expectations model. *Journal of Economic Dynamics and Control 24*(10), 1405–1423.

Krusell, P. and A. A. Smith (1998, October). Income and wealth heterogeneity in the macroeconomy. *Journal of Political Economy 106*(5), 867–896.

Lafrance, R., P. Osakwe, and P. St-Amant (1998). Evaluating alternative measures of the real effective exchange rate. Working Papers 98-20, Bank of Canada.

Lambertini, L., C. Mendicino, and M. T. Punzi (2010a, July). Expectations-driven cycles in the housing market. Banco de España Working Papers 1021, Banco de España.

Lambertini, L., C. Mendicino, and M. T. Punzi (2010b). Expectations-driven cycles in the housing market. Working Papers w201004, Banco de Portugal, Economics and Research Department.

Lambertini, L., C. Mendicino, and M. T. Punzi (2011). Leaning against boom-bust cycles in credit and housing prices. Working Papers CELEG 1104, Department of Economic and Business Sciences, LUISS Guido Carli.

Lambertini, L., C. Mendicino, and M. Teresa Punzi (2013). Leaning against boom–bust cycles in credit and housing prices. *Journal of Economic Dynamics and Control 37*(8), 1500–1522.

Larsson, R., J. Lyhagen, and M. Lothgren (2001). Likelihood-based cointegration tests in heterogeneous panels. *Econometrics Journal 4*(1), 41.

Leeper, E. and T. Walker (2011, January). Information flows and news driven business cycles. *Review of Economic Dynamics 14*(1), 55–71.

Leeper, E. M., T. B. Walker, and S.-C. S. Yang (2008, May). Fiscal foresight : Analytics and econometrics. NBER Working Papers 14028, National Bureau of Economic Research, Inc.

Leung, D. and T. Yuen (2005). Labour market adjustments to exchange rate fluctuations : evidence from Canadian manufacturing industries. Working Papers 05-14, Bank of Canada.

Leung, D. and T. Yuen (2007, April). Labour market adjustments to exchange rate fluctuations : Evidence from Canadian manufacturing industries. *Open Economies Review 18*(2), 177–189.

Levin, A., C.-F. Lin, and C.-S. James Chu (2002, May). Unit root tests in panel data : asymptotic and finite-sample properties. *Journal of Econometrics 108*(1), 1–24.

Levin, A. T., A. Onatski, J. Williams, and N. M. Williams (2006, September). Monetary policy under uncertainty in micro-founded macroeconometric models. In *NBER Macroeconomics Annual 2005, Volume 20*, NBER Chapters, pp. 229–312. National Bureau of Economic Research, Inc.

Lubik, T. and F. Schorfheide (2006, September). A bayesian look at the new open economy macroeconomics. In *NBER Macroeconomics Annual 2005, Volume 20*, NBER Chapters, pp. 313–382. National Bureau of Economic Research, Inc.

Maddala, G. S. and S. Wu (1999, Special I). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics 61*(0), 631–52.

Mark, N. C. and D. Sul (2003, December). Cointegration vector estimation by panel DOLS and long-run money demand. *Oxford Bulletin of Economics and Statistics 65*(5), 655–680.

McCoskey, S. and C. Kao (1998). A residual-based test of the null of cointegration in panel data. *Econometric Reviews 17*(1), 57–84.

Milani, F. and J. Treadwell (2011). The effects of monetary policy news and surprises. Working paper, University of California, Irvine.

Monacelli, T. (2009, March). New keynesian models, durable goods, and collateral constraints. *Journal of Monetary Economics 56*(2), 242–254.

Moon, H. R. and B. Perron (2004, September). Testing for a unit root in panels with dynamic factors. *Journal of Econometrics 122*(1), 81–126.

Moscone, F. and E. Tosetti (2009, 07). A review and comparison of tests of cross-section independence in panels. *Journal of Economic Surveys 23*(3), 528–561.

Negro, M. D. and S. Eusepi (2010). Fitting observed inflation expectations. Staff Reports 476, Federal Reserve Bank of New York.

Nickell, S. (1987, April). Dynamic models of labour demand. In O. Ashenfelter and R. Layard (Eds.), *Handbook of Labor Economics*, Volume 1 of *Handbook of Labor Economics*, Chapter 9, pp. 473–522. Elsevier.

O'Connell, P. G. J. (1998, February). The overvaluation of purchasing power parity. *Journal of International Economics 44*(1), 1–19.

Palm, F. C., S. Smeekes, and J.-P. Urbain (2011, July). Cross-sectional dependence robust block bootstrap panel unit root tests. *Journal of Econometrics 163*(1), 85–104.

Patton, A. J. and A. Timmermann (2007, December). Testing forecast optimality under unknown loss. *Journal of the American Statistical Association 102*, 1172–1184.

Pedroni, P. (1996). Fully modified OLS for heterogeneous cointegrated panels and the case of purchasing power parity . Working paper in economics, Indiana University.

Pedroni, P. (1999, Special I). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics 61*(0), 653–70.

Pedroni, P. (2001, November). Purchasing power parity tests in cointegrated panels. *The Review of Economics and Statistics 83*(4), 727–731.

Pedroni, P. (2004, June). Panel cointegration : Asymptotic and finite sample properties of pooled time series tests with an application to the ppp hypothesis. *Econometric Theory 20*(03), 597–625.

Pesaran, M. H. (2004, August). General diagnostic tests for cross section dependence in panels. IZA Discussion Papers 1240, Institute for the Study of Labor (IZA).

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics 22*(2), 265–312.

Pesaran, M. H., Y. Shin, and R. P. Smith (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association 94*(446), pp. 621–634.

Phillips, P. C. B. and B. E. Hansen (1990, January). Statistical inference in instrumental variables regression with I(1) processes. *Review of Economic Studies 57*(1), 99–125.

Phillips, P. C. B. and H. R. Moon (1999, September). Linear regression limit theory for nonstationary panel data. *Econometrica 67*(5), 1057–1112.

Phillips, P. C. B. and H. R. Moon (2000). Nonstationary panel data analysis : an overview of some recent developments. *Econometric Reviews 19*(3), 263–286.

Politis, D. N. and J. Romano (1994). The stationary bootstrap. *Journal of American Statististical Association 89*, 1303–1313.

Politis, D. N. and H. White (2004). Automatic block-length selection for the dependent bootstrap. *Econometric Reviews 23*(1), 53–70.

Politis, D. N., H. White, and A. J. Patton (2009). Correction : Automatic block-length selection for the dependent bootstrap. *Econometric Reviews 28*(4), 372–375.

Saikkonen, P. (1991). Asymptotically efficient estimation of cointegration regressions. *Econometrica 7*(1), 1–21.

Schmitt-Grohé, S. and M. Uribe (2007, Junio). Optimal inflation stabilization in a medium-scale macroeconomic model. In F. S. Miskin, K. Schmidt-Hebbel, N. L. S. Editor), and K. S.-H. (Se (Eds.), *Monetary Policy under Inflation Targeting*, Volume 11 of *Central Banking, Analysis, and Economic Policies Book Series*, Chapter 5, pp. 125–186. Central Bank of Chile.

Schmitt-Grohe, S. and M. Uribe (2012). What's news in business cycles. *Econometrica 80*(6), 2733–2764.

Sims, C. A. (1980, January). Macroeconomics and reality. *Econometrica 48*(1), 1–48.

Sims, C. A. (2002, October). Solving linear rational expectations models. *Computational Economics 20*(1-2), 1–20.

Smets, F. R. and R. Wouters (2003, 09). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association 1*(5), 1123–1175.

Smets, F. R. and R. Wouters (2007, June). Shocks and frictions in us business cycles : A bayesian dsge approach. *American Economic Review 97*(3), 586–606.

Smith, L. V., S. Leybourne, T.-H. Kim, and P. Newbold (2004). More powerful panel data unit root tests with an application to mean reversion in real exchange rates. *Journal of Applied Econometrics 19*(2), 147–170.

Stock, J. H. and M. W. Watson (1993, July). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica 61*(4), 783–820.

Strauss, J. and T. Yigit (2003, December). Shortfalls of panel unit root testing. *Economics Letters 81*(3), 309–313.

Swensen, A. R. (2006, November). Bootstrap algorithms for testing and determining the cointegration rank in var models -super-1. *Econometrica 74*(6), 1699–1714.

Taylor, J. B. (1993, December). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy 39*(1), 195–214.

Wagner, M. and J. Hlouskova (2010). The performance of panel cointegration methods : Results from a large scale simulation study. *Econometric Reviews 29*(2), 182–223.

Westerlund, J. (2005). New simple tests for panel cointegration. *Econometric Reviews 24*(3), 297–316.

Westerlund, J. and D. L. Edgerton (2007, December). A panel bootstrap cointegration test. *Economics Letters 97*(3), 185–190.

Yun, T. (1996, April). Nominal price rigidity, money supply endogeneity, and business cycles. *Journal of Monetary Economics 37*(2-3), 345–370.

Deuxième partie

Appendices

Appendix 1

Appendix of Chapter 1

1.1 Definitions and Data Sources

Recovering News Shocks

3-months Treasury-Bill rate

1981Q3 to 2010Q4 data

Median responses of forecast of the quarterly 3-months Treasury-Bill rate. It is a quarterly average in percentage points not seasonally adjusted.

Source: Federal Reserve Bank of St. Louis (Survey of Professional Forecasters), Internal Calculations

CPI inflation rate

1981Q3 to 2010Q4 data

Median responses of forecast of the annualized quarterly CPI inflation rate. It is a annualized percentage points, seasonally adjusted, based on quarterly average index level.

Source: Federal Reserve Bank of St. Louis(Survey of Professional Forecasters), Internal Calculations

Real GDP growth rate

1981Q3 to 2010Q4 data

Median responses of forecast of the annualized quarterly real GDP growth rate. It is based on real GDP forecasts in billions of real dollars, seasonally adjusted at annual rate. Real GNP prior to 1992. Real GDP 1992-present.

Source: Federal Reserve Bank of St. Louis (Survey of Professional Forecasters), Internal Calculations

Vector Autoregressive

Real GDP

1981Q3 to 2011Q4 data

Real (chained 2005 dollars) gross domestic product, seasonally adjusted at annual rate.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

Real private consumption

1981Q3 to 2011Q4 data

Real (chained 2005 dollars) personal consumption expenditures, seasonally adjusted at annual rate.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

Real durable goods consumption

1981Q3 to 2011Q4 data

Real (chained 2005 dollars) personal consumption expenditures on durable goods, seasonally adjusted at annual rate.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

Real price of durable goods

1981Q3 to 2011Q4 data

Price index for durable goods (2005 = 100), seasonally adjusted.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

CPI

1981Q3 to 2011Q4 data

Consumer price index for all urban consumers, all Items.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

Treasury-Bill 3-months secondary market rate

1981Q3 to 2011Q4 data

3-Month Treasury Bill, Secondary Market Rate, not seasonally adjusted.

Source: Federal Reserve Bank of St. Louis (FRED) and Bureau of Economic Analysis, Internal Calculations

1.2 Recovering News Shocks: State-space Formulation

For our baseline specification, the measurement equation has the following elements:

$$y_t = \begin{bmatrix} E_t\left(R_t\right) \\ E_t\left(R_{t+1}\right) \\ E_t\left(R_{t+2}\right) \\ E_t\left(R_{t+3}\right) \\ E_t\left(R_{t+4}\right) \end{bmatrix}, u_t = \begin{bmatrix} 1 \\ E_t\left(R_{t-1}\right) \\ E_t\left(R_t\right) \\ E_t\left(R_{t+1}\right) \\ E_t\left(R_{t+2}\right) \\ E_t\left(R_{t+3}\right) \\ E_t\left(\pi_t - \pi^*\right) \\ E_t\left(\pi_{t+1} - \pi^*\right) \\ E_t\left(\pi_{t+2} - \pi^*\right) \\ E_t\left(\pi_{t+3} - \pi^*\right) \\ E_t\left(\pi_{t+4} - \pi^*\right) \\ E_t\left(\hat{y}_t - \hat{y}^*\right) \\ E_t\left(\hat{y}_{t+1} - \hat{y}^*\right) \\ E_t\left(\hat{y}_{t+2} - \hat{y}^*\right) \\ E_t\left(\hat{y}_{t+3} - \hat{y}^*\right) \\ E_t\left(\hat{y}_{t+4} - \hat{y}^*\right) \end{bmatrix},$$

and D is a 5×25 matrix with elements 0 and 1; and E is a 5×16 matrix with elements 0 and the parameters of the monetary policy rule, which are the constant C, ρ_R, ρ_π and ρ_y.

The state equation has the following elements:

$$x_{t+1} = \begin{bmatrix} \epsilon^0_{t+1} \\ \epsilon^1_{t+1} \\ \epsilon^2_{t+1} \\ \epsilon^3_{t+1} \\ \epsilon^4_{t+1} \\ \epsilon^0_{t} \\ \epsilon^1_{t} \\ \epsilon^2_{t} \\ \epsilon^3_{t} \\ \epsilon^4_{t} \\ \epsilon^0_{t-1} \\ \epsilon^1_{t-1} \\ \epsilon^2_{t-1} \\ \epsilon^3_{t-1} \\ \epsilon^4_{t-1} \\ \epsilon^0_{t-2} \\ \epsilon^1_{t-2} \\ \epsilon^2_{t-2} \\ \epsilon^3_{t-2} \\ \epsilon^4_{t-2} \\ \epsilon^0_{t-3} \\ \epsilon^1_{t-3} \\ \epsilon^2_{t-3} \\ \epsilon^3_{t-3} \\ \epsilon^4_{t-3} \end{bmatrix}, x_t = \begin{bmatrix} \epsilon^0_{t} \\ \epsilon^1_{t} \\ \epsilon^2_{t} \\ \epsilon^3_{t} \\ \epsilon^4_{t} \\ \epsilon^0_{t-1} \\ \epsilon^1_{t-1} \\ \epsilon^2_{t-1} \\ \epsilon^3_{t-1} \\ \epsilon^4_{t-1} \\ \epsilon^0_{t-2} \\ \epsilon^1_{t-2} \\ \epsilon^2_{t-2} \\ \epsilon^3_{t-2} \\ \epsilon^4_{t-2} \\ \epsilon^0_{t-3} \\ \epsilon^1_{t-3} \\ \epsilon^2_{t-3} \\ \epsilon^3_{t-3} \\ \epsilon^4_{t-3} \\ \epsilon^0_{t-4} \\ \epsilon^1_{t-4} \\ \epsilon^2_{t-4} \\ \epsilon^3_{t-4} \\ \epsilon^4_{t-4} \end{bmatrix}, w_{t+1} = \begin{bmatrix} \epsilon^0_{t+1} \\ \epsilon^1_{t+1} \\ \epsilon^2_{t+1} \\ \epsilon^3_{t+1} \\ \epsilon^4_{t+1} \end{bmatrix},$$

and A is a 25×25 matrix with elements 0 and 1; C is a 25×5 matrix with elements 0 and 1; and Q is a 5×5 matrix with elements 0 and variances of the shocks, which are $\sigma^2_{\epsilon^0}$,

$\sigma^2_{\epsilon^1}$, $\sigma^2_{\epsilon^2}$, $\sigma^2_{\epsilon^3}$ and $\sigma^2_{\epsilon^4}$.

For our alternative specification, the only modifications is the removal of the inflation rate target, π^*, and real potential GDP growth rate target, $\hat{y}^*$ in vector u.

Appendix 2

Appendix of Chapter 2

2.1 Definitions and Data Sources

Industry-Specific Data - *KLEMS*

Labour input ($l_{i,t}$)

1961 to 2008 data

Labour inputs, by manufacturing industry at the NAICS 3-digit (industry) level. This index is obtained by chained Fisher aggregation of hours worked across all workers, classified by education, work experience and class of workers (paid workers, as opposed to self-employed and unpaid family workers) using hourly compensation as weights.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

Hours worked ($h_{i,t}$)

1961 to 2008 data

Hours worked, by manufacturing industry at the NAICS 3-digit level. The number of hours worked in all jobs is the number of all jobs times the annual average hours worked in all jobs. According to the retained definition, hours worked means the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers retain their positions. On the other hand, time lost due to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs are not included in total hours worked.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

Jobs ($j_{i,t}$)

1961 to 2008 data

Total number of jobs (full- and part-time), by manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada, Internal Calculations

Relative price of labour ($w_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the compensation index and the Fisher volume index of labour deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level. Labour compensation includes all payments in cash or in kind made by domestic producers to workers for services rendered, i.e. total payroll. It includes the salaries and supplementary labour income of paid workers, plus an imputed labour income for self-employed workers. The Industrial Product Price Index (IPPI) measures price changes for major commodities sold by manufacturers in Canada. The prices collected are for goods sold at the factory gate. As a result, the prices covered by the IPPI are those received by the producer rather than those paid by the purchaser. They exclude all indirect taxes, such as sales taxes and tariffs, because this money is not paid to production factors (labour, capital, other inputs), or profit. They also exclude any transportation service performed by a common carrier beyond the factory gate and any distribution services performed by the retail or wholesale trade industries.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of capital ($p^K_{i,t}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the capital cost index and the Fisher volume index of capital inputs deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level. Capital costs represents the surplus profits, depreciation, rent and net interest intended as compensation to the owners of capital. It is calculated as the nominal GDP at basic prices minus labour compensation.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of intermediate inputs ($p_{i,t}^{II}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the intermediate inputs cost index and the Fisher volume index of intermediate inputs by manufacturing industry deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of energy ($p_{i,t}^{E}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of energy cost index and the Fisher volume index of energy inputs by manufacturing industries deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of materials ($p_{i,t}^{M}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the materials cost index and the Fisher volume index of material inputs deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Relative price of services ($p_{i,t}^{S}$)

1961 to 2008 data

Chained Fisher index of prices, calculated as the ratio of the cost of services index and the Fisher volume index of service inputs deflated by the industrial product price index, for each manufacturing industry at the NAICS 3-digit level.

Source: Statistics Canada (Cansim Tables 329-0038 and 383-0022), Internal Calculations

Multifactor productivity $(a_{i,t})$

1961 to 2008 data

Multifactor productivity based on gross output measures the efficiency with which all inputs including capital, labour and intermediate inputs are used in production. It is the ratio of real gross output to combined units of all inputs.

Source: Statistics Canada (Cansim Table 383-0022), Internal Calculations

Aggregate Data

Real effective exchange rate (s_t)

1961 to 2008 data

Nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade and deflated by the pairwise relative CPIs of the countries.

Source: Bruegel (http://www.bruegel.org/datasets/real-effective-exchange-rates-for-178-countries-a-new-database/)

Real effective exchange rate (first alternative: Unit Labour Costs) (s_t)

1971 to 2008 data

Nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade and deflated by the pairwise relative Unit Labour Costs in countries.

Source: OECD (http://stats.oecd.org/index.aspx)

Real effective exchange rate (second alternative: No Deflating for Prices) (s_t)

1961 to 2008 data

Nominal exchange rate between Canada and its major trading partners, weighted by their respective shares in Canada's international trade. Extracted from a database of real exchange rates for 178 countries from Bruegel in Brussels.

Source: Bruegel (http://www.bruegel.org/datasets/real-effective-exchange-rates-for-178-countries-

a-new-database/)

G7 real gross domestic product (y_t^{all})

1961 to 2008 data

Simple sum aggregate of $G7$ real GDPs evaluated at PPP.

Source: OECD (OECD.StatExtracts (http://stats.oecd.org/). Subject: "B1 GE: Gross domestic product - expenditure approach"; measure: "VIXOBSA: Volume index, OECD reference year, seasonally adjusted".)

CUSFTA dummy ($CUSFTA_t$)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning on and after 1989 and 0 before 1989, to signal the enactment of the Canada-U.S. Free Trade Agreement.

NAFTA dummy ($NAFTA_t$)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning on and after 1994 and 0 before 1994, to signal the enactment of the North-American Free Trade Agreement.

FEX dummy (FEX_t)

1961 to 2008 data

A dummy variable that takes a value of 1 beginning on and after 1976, to signal the completion of the transition towards a freely floating exchange rate between Canada's currency and that of its trading partners. 1976 is the year of the Jamaica Accord, which ratified the end of the Bretton-Woods system of fixed exchange rates. The presence of a break at this date is supported by a Hansen (1997) test.

2.2 Industry Classification by Net Exposure to International Trade

Table 2.1: List of Industries by Net Trade Exposure and Export Intensity

NAICS	Manufacturing Industries	NTE	EI
311	Food	Low	Low
312	Beverage and tobacco product	Low	Low
313 & 314	Textile mills & Textile product mills	High	Low
315	Clothing	High	Low
316	Leather and allied product	High	Low
321	Wood product	High	High
322	Paper	High	High
323	Printing and related support activities	Low	Low
324	Petroleum and coal product	Low	Low
325	Chemical	High	High
326	Plastics and rubber product	High	High
327	Non-metallic mineral product	Low	Low
331	Primary metal	Low	High
332	Fabricated metal product	High	Low
333	Machinery	High	High
334	Computer and electronic product	High	High
335	Electrical equipment, appliance and component	High	High
336	Transportation	High	High
337	Furniture and related product	High	High
339	Miscellaneous	High	Low

2.3 Derivation of the Labour Input Demand

Frictionless (*Long-run*) Labour Demand

Consider the typical manufacturing firm j in industry i. Assume this firm produces $y_{i,j,t}$ using the following CES production function using labour ($l^*_{i,j,t}$) and capital ($k_{i,j,t}$) inputs:

$$y_{i,j,t} = a_{i,t} \left[{l^*_{i,j,t}}^{\frac{\alpha-1}{\alpha}} + \kappa^{\frac{1}{\alpha}} {k_{i,j,t}}^{\frac{\alpha-1}{\alpha}} \right]^{\frac{\alpha}{\alpha-1}}, \tag{2.1}$$

where $a_{i,t}$ is (industry-specific) multifactor productivity and α the elasticity of substitution between the two inputs.

Denote the industry-specific prices of labour and capital by $w_{i,t}$ and $p^k_{i,t}$, respectively, so that total costs for the firm is $tc_{i,j,t} = w_{i,t} l^*_{i,j,t} + p^k_{i,t} k_{i,j,t}$. Minimizing total costs $tc_{i,j,t}$ under the constraint of producing a given level of output yields the following cost curve:

$$tc_{i,t} = mc_{i,t} y_{i,j,t},$$

where $y_{i,j,t}$ is the chosen level of production and marginal cost $mc_{i,t}$ is common across firms of the same industry:

$$mc_{i,t} = \frac{\left[{w_{i,t}}^{1-\alpha} + \kappa {p^k_{i,t}}^{1-\alpha} \right]^{\frac{1}{1-\alpha}}}{a_{i,t}}. \tag{2.2}$$

In addition, the following labour input demand obtains from the cost-minimization problem:

$$l^*_{i,j,t} = y_{i,j,t} {mc_{i,t}}^{\alpha} {a_{i,t}}^{\alpha-1} {w_{i,t}}^{-\alpha}. \tag{2.3}$$

Next, let firm j face the following constant-elasticity demand for its product, originating both from domestic and foreign markets:

$$y^d_{i,j,t} = \left(\frac{P_{i,j,t}}{P_t} \right)^{-\theta} Y_t + \chi_{i,t} \left(\frac{P_{i,j,t} E_t}{P^*_t} \right)^{-\theta} Y^*_t, \tag{2.4}$$

where $P_{i,j,t}$ is the (domestic currency) price charged by the firm, E_t is the nominal exchange rate, P_t and P_t^* are the general price levels in the domestic and the foreign country, respectively, Y_t and Y_t^* are measures of general economic activity in these two markets and θ is the price-elasticity of demand. The term $\chi_{i,t}$ denotes industry-specific shifts to demand, perhaps arising from new trade agreements. Denoting the relative price of the firm's product as $p_{i,j,t} \equiv P_{i,j,t}/P_t$ and the real exchange rate by $s_t \equiv E_t P_t / P_t^*$, one can rewrite (2.4) as

$$y_{i,j,t}^d = {p_{i,j,t}}^{-\theta} \left(Y_t + \chi_{i,t} s_t Y_t^* \right) = {p_{i,j,t}}^{-\theta} x_{i,t}, \tag{2.5}$$

where we have defined the product-demand shifter $x_{i,t} \equiv (Y_t + \chi_{i,t} s_t Y_t^*)$.

Profit maximization is then the following problem:

$$\max_{p_{i,j,t}} p_{i,j,t} y_{i,j,t} - mc_{i,t} y_{i,j,t},$$

subject to (2.5). The solution to this problem is to set prices at a constant markup over marginal cost for all firms, thus allowing us to drop the indice j from its expression:

$$p_{i,t} = \frac{\theta}{\theta - 1} mc_{i,t} = \mu \, mc_{i,t}.$$

Using (2.5) then allows us to back-out the (common) product demand at the optimal price:

$$y_{i,t} = \left(\mu mc_{i,t} \right)^{-\theta} x_{i,t},$$

and, using (2.3), the labour input necessary to satisfy this demand:

$$l_{i,t}^* = \mu^{-\theta} {mc_{i,t}}^{\alpha - \theta} x_{i,t} {a_{i,t}}^{\alpha - 1} {w_{i,t}}^{-\alpha}. \tag{2.6}$$

Finally, using (2.2) to replace marginal costs and taking a first-order approximation yields the labour demand equation, expressed in log-deviations from steady-state:

$$\ln l_{i,t}^* = -\left(\left(1 - sh^l \right) \alpha + sh^l \theta \right) \ln w_{i,t} + (\alpha - \theta) \, sh^k \ln p_{i,t}^k + (\theta - 1) \ln a_{i,t} + \ln x_{i,t}, \tag{2.7}$$

with sh^l the labour share of total costs and sh^k the capital share. This recovers the frictionless labour demand (2.3) in the text and defines the cointegrating relation we estimate. Notice that the coefficient on $\ln w_t$ is unambiguously negative but that the sign on capital's coefficient, $(\alpha - \theta)sh^k$ depends on the value of the elasticity of substitution between inputs α.[1] Further, the impact of technology is positive, with a magnitude equal to $\theta - 1$.[2]

Note that equation (2.7) represents only the demand side of labour market equilibrium in each manufacturing industry. Nevertheless, interpreting them as cointegration relationship allows us to estimate them without creating any econometric problem due to endogeneity.

Dynamic Adjustment Towards the Frictionless Labour Demand

Now consider quadratic adjustment costs to labour that prevent a frictionless labour input choice (Nickell, 1987; Hamermesh and Pfann, 1996). Profit maximization becomes

$$\max_{\{l_{i,t},k_{i,t}\}} E_0 \sum_{t=0}^{\infty} \delta^t \left[p_{i,t} y_{i,t} - w_{i,t} l_{i,t} - p^k_{i,t} k_{i,t} - w_{i,t} \frac{b}{2} (l_{i,t} - l_{i,t-1})^2 \right], \tag{2.8}$$

subject to (2.5) and (2.1), where δ is the discount factor applied to future dividends and b indexes the extent of the adjustment costs. Nickell (1987) shows that a first-order approximate solution to (2.8) has the following partial adjustment process

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu)(1-\delta g \nu) E_t \left[\sum_{\tau=0}^{\infty} (\delta g \nu)^{\tau} \ln l^*_{i,t+\tau} \right], \tag{2.9}$$

where ν depends on the adjustment costs, g is the long term real wage growth trend and $l^*_{i,t}$ is the frictionless ($b = 0$) labour demand from (2.7). Labour demand for the typical

[1] An increase in p^k has two opposite effects on labour. On the one hand, it raises marginal costs which, through the price-setting rule, leads to price increases and thus declines in product demand, which implies a decrease in the labour input. On the other hand, it leads firms to substitute away from capital towards labour for a given production level. This latter effect dominate when $\alpha > \theta$ thus the labour input increases.

[2] A rise in productivity decreases marginal costs and thus prices, again through the price-setting rule. The extent to which this increases product demand – and therefore labour input – depends on θ. In environments where θ is low (ie. products have relatively few substitutes), one would expect the impact of productivity on labour demand to be low.

firm in industry i thus follows a partial adjustment process that gradually attains a target equal to a geometric sum of future expected values of $l^*_{i,t}$, with the speed of adjustment $1-\nu$ depending on the severity of adjustment costs. If changes in the variables affecting $l^*_{i,t}$ are largely permanent (an hypothesis validated by our unit root analysis), (2.9) simplifies to

$$\ln l_{i,t} = \nu \ln l_{i,t-1} + (1-\nu) \ln l^*_{i,t},$$

as in the text.

Appendix 3

Appendix of Chapter 3

3.1 Definitions and Data Sources

Consumption (c_t)

1983Q2 to 2012Q2 data

Real (chained 2007 dollars) household consumption expenditure on non-durable goods, semi-durable goods and services per capita (number of persons of working age, 15 years and over), seasonally adjusted at annual rates. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 282-0001 and 380-0064), Internal Calculations

Core CPI inflation rate (π_t^c)

1983Q2 to 2012Q2 data

All-items CPI excluding eight of the most volatile components and the core CPI. We splice both series, compute the annualized quarterly growth rate and remove the Bank of Canada's inflation target of 2 percent.

Source: Statistics Canada (Table 326-0020), Internal Calculations

Residential investment (y_t^h)

1983Q2 to 2012Q2 data

Real (chained 2007 dollars) business gross fixed capital formation in residential structures per capita (number of persons of working age, 15 years and over), seasonally adjusted at annual rates. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 282-0001 and 380-0064), Internal Calculations

House price inflation rate (π_t^h)

1983Q2 to 2012Q2 data

Nominal house prices. We compute the annualised quarterly growth rate and remove the Bank of Canada's inflation target of 2 percent.

Source: Multiple Listing Service (MLS)

Non-residential investment (i_t^k)

1983Q2 to 2012Q2 data

Real (chained 2007 dollars) business gross fixed capital formation in non-residential structures, machinery and equipment per capita (number of persons of working age, 15 years and over), seasonally adjusted at annual rates. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 282-0001 and 380-0064), Internal Calculations

Capital price inflation rate (π_t^k)

1983Q2 to 2012Q2 data

Nominal implicit price index of business gross fixed capital formation in non-residential structures, machinery and equipment. We compute the annualised quarterly growth rate and remove the Bank of Canada's inflation target of 2 percent.

Source: Statistics Canada (Cansim Table 380-0066), Internal Calculations

Mortgage debt ($b_{i,t}$)

1983Q2 to 2012Q2 data

Real (core CPI) residential mortgage credit per capita (number of persons of working age, 15 years and over), seasonally adjusted. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 282-0001 and 176-0069), Internal Calculations

Nominal short-term interest rate (R_t)

1983Q2 to 2012Q2 data

Treasury bills rate, 3-months. We remove a linear trend.

Source: Statistics Canada (Cansim Table 176-0043), Internal Calculations

Nominal long-term interest rate (R_t^m)

1983Q2 to 2012Q2 data

Average residential mortgage lending rate, 5 years. We remove a linear trend.

Source: Statistics Canada (Cansim Table 176-0043), Internal Calculations

Hours worked in consumption sector (n_t^c)

1983Q2 to 2012Q2 data

Hours worked in the consumption sector per capita (number of persons of working age, 15 years and over). The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 281-0001, 281-0002, 281-0023, 281-0026 and 282-0001), Internal Calculations

Wage inflation rate in consumption sector ($\pi_t^{w^c}$)

1983Q2 to 2012Q2 data

Nominal wages in the consumption sector. The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the Bank of Canada's inflation target of 2 percent.

Source: Statistics Canada (Cansim Tables 281-0004 and 281-0031), Internal Calculations

Capacity utilization rate in consumption sector ($u_t^{k^c}$)

1983Q2 to 2012Q2 data

Capacity utilization rate in the consumption sector. The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 028-0001, 028-0002 and 031-0003), Internal Calculations

Hours worked in housing sector (n_t^h)

1983Q2 to 2012Q2 data

Hours worked in the housing sector per capita (number of persons of working age, 15 years and over). The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Table 281-0001, 281-0002, 281-0023, 281-0026 and 282-0001), Internal Calculations

Wage inflation rate in housing sector ($\pi_t^{w^h}$)

1983Q2 to 2012Q2 data

Nominal wages in the housing sector. The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the Bank of Canada's inflation target of 2 percent.

Source: Statistics Canada (Cansim Tables 281-0004 and 281-0031), Internal Calculations

Capacity utilization rate in housing sector ($u_t^{k^h}$)

1983Q2 to 2012Q2 data

Capacity utilization rate in the housing sector. The full computation methodology for this series is available upon request. We compute the annualised quarterly growth rate and remove the mean.

Source: Statistics Canada (Cansim Tables 028-0001, 028-0002 and 031-0003), Internal Calculations

3.2 Figures

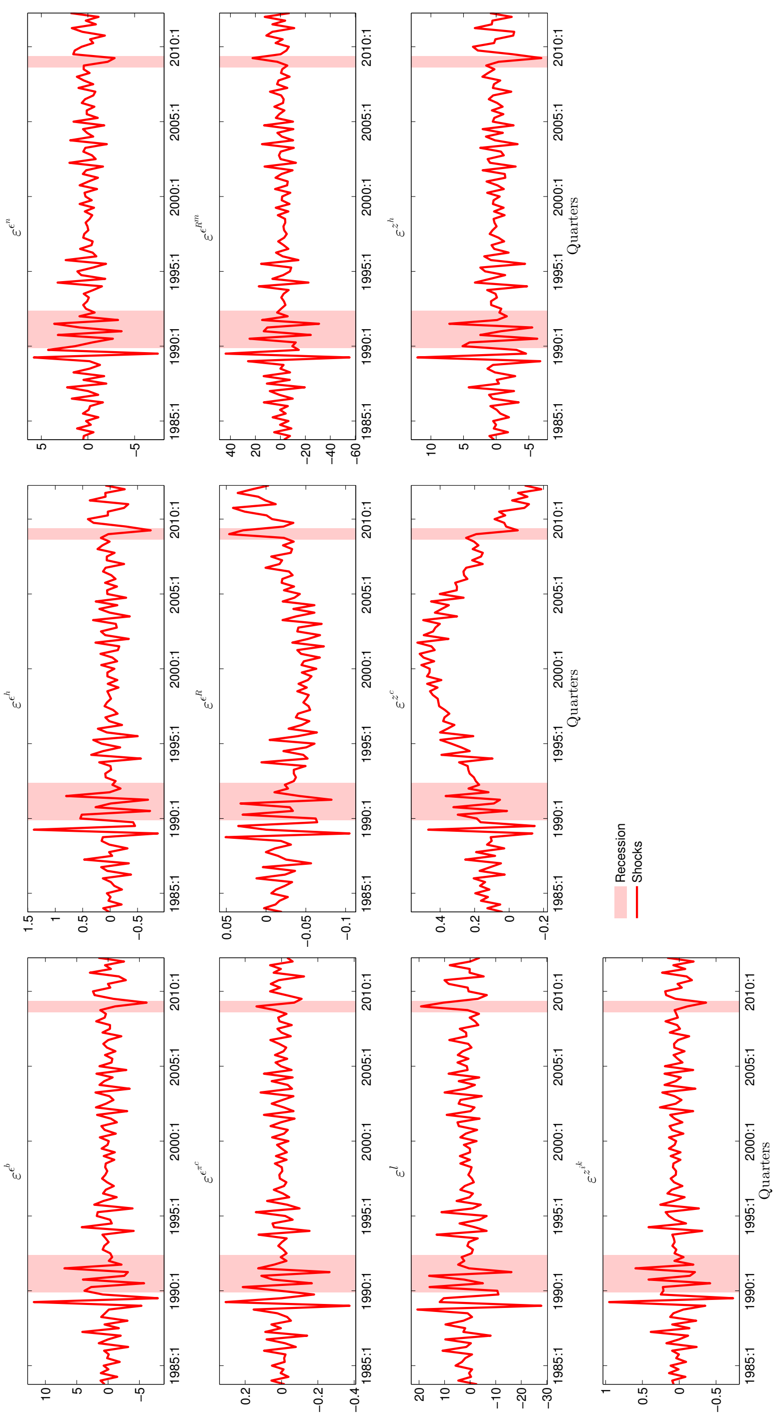


Figure 3.1: Estimated (Smoothed) Shocks, from 1983Q2 to 2012Q2

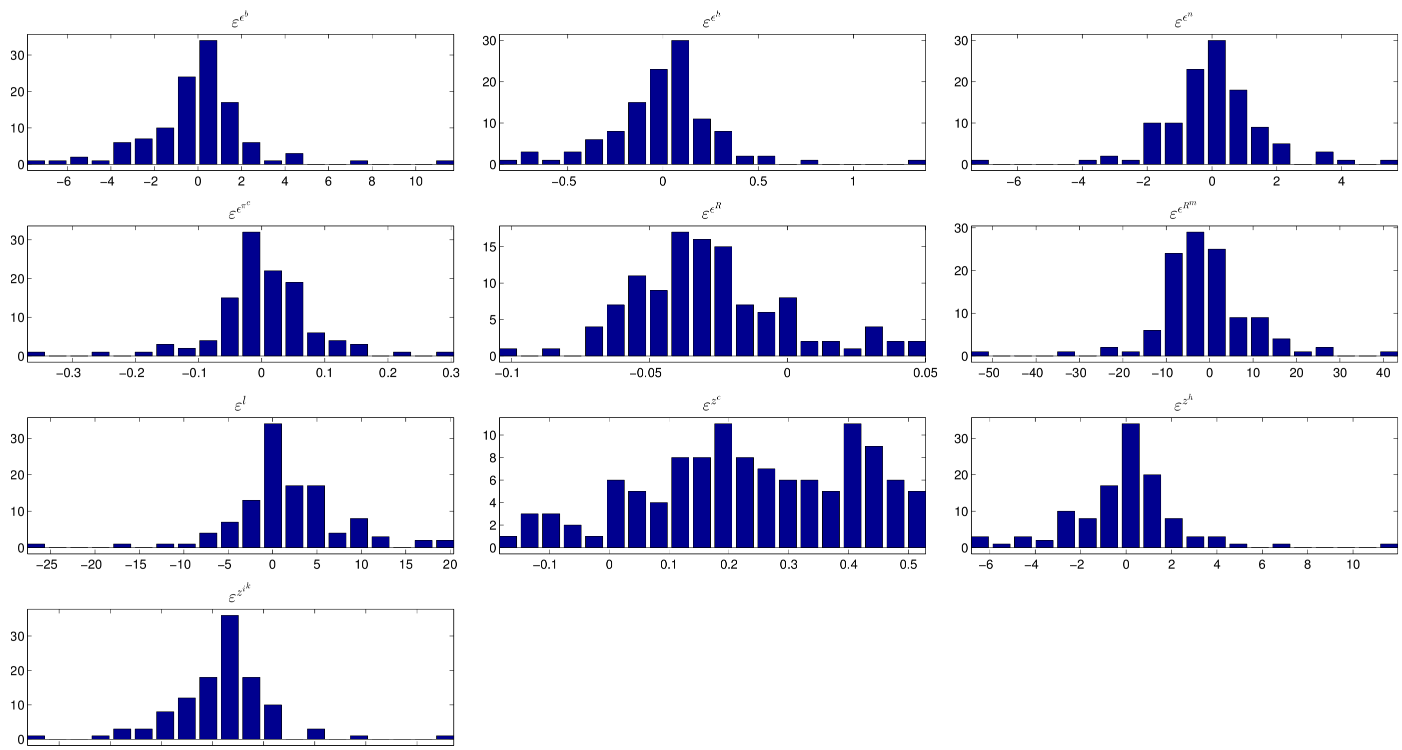


Figure 3.2: Histograms of Estimated (Smoothed) Shocks, from 1983Q2 to 2012Q2

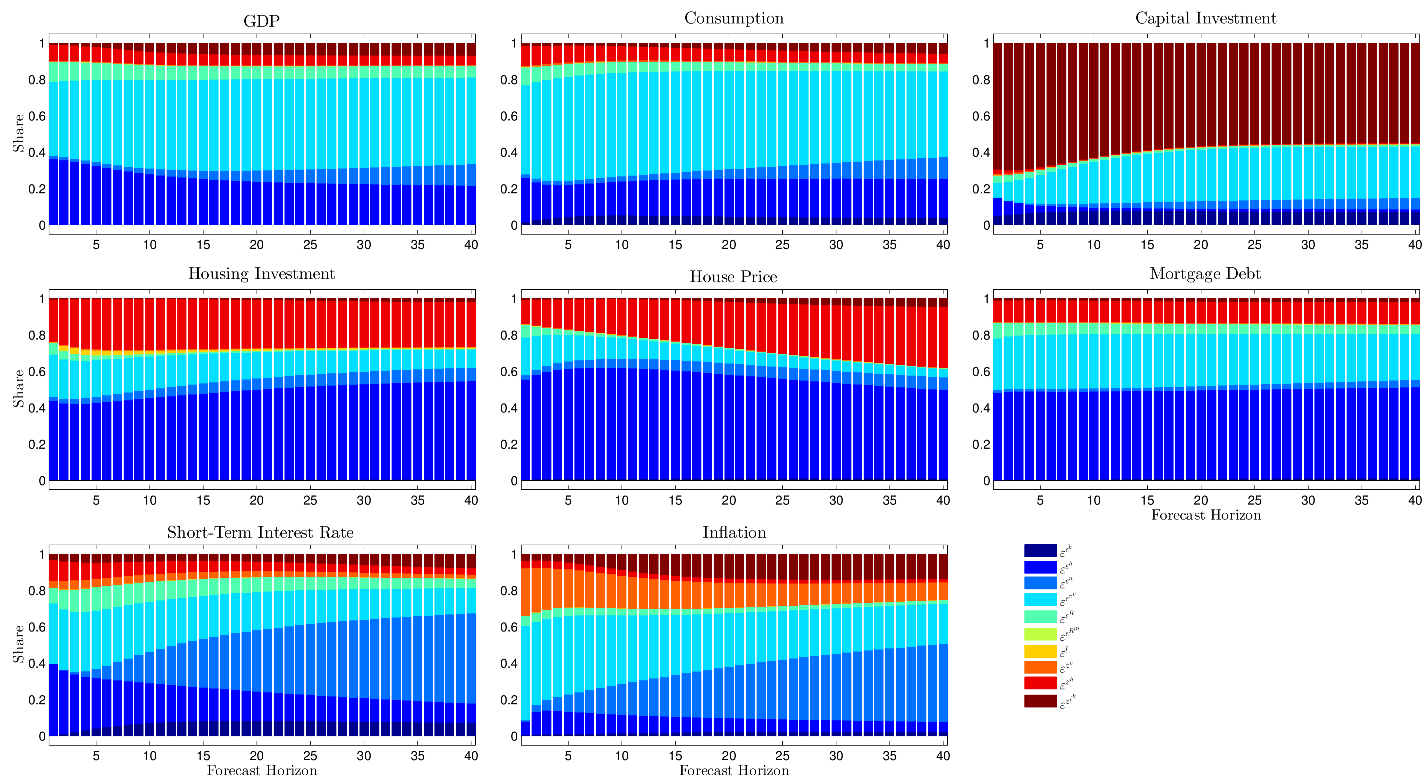


Figure 3.3: Forecast Error Variance Decomposition for Selected Model Variables

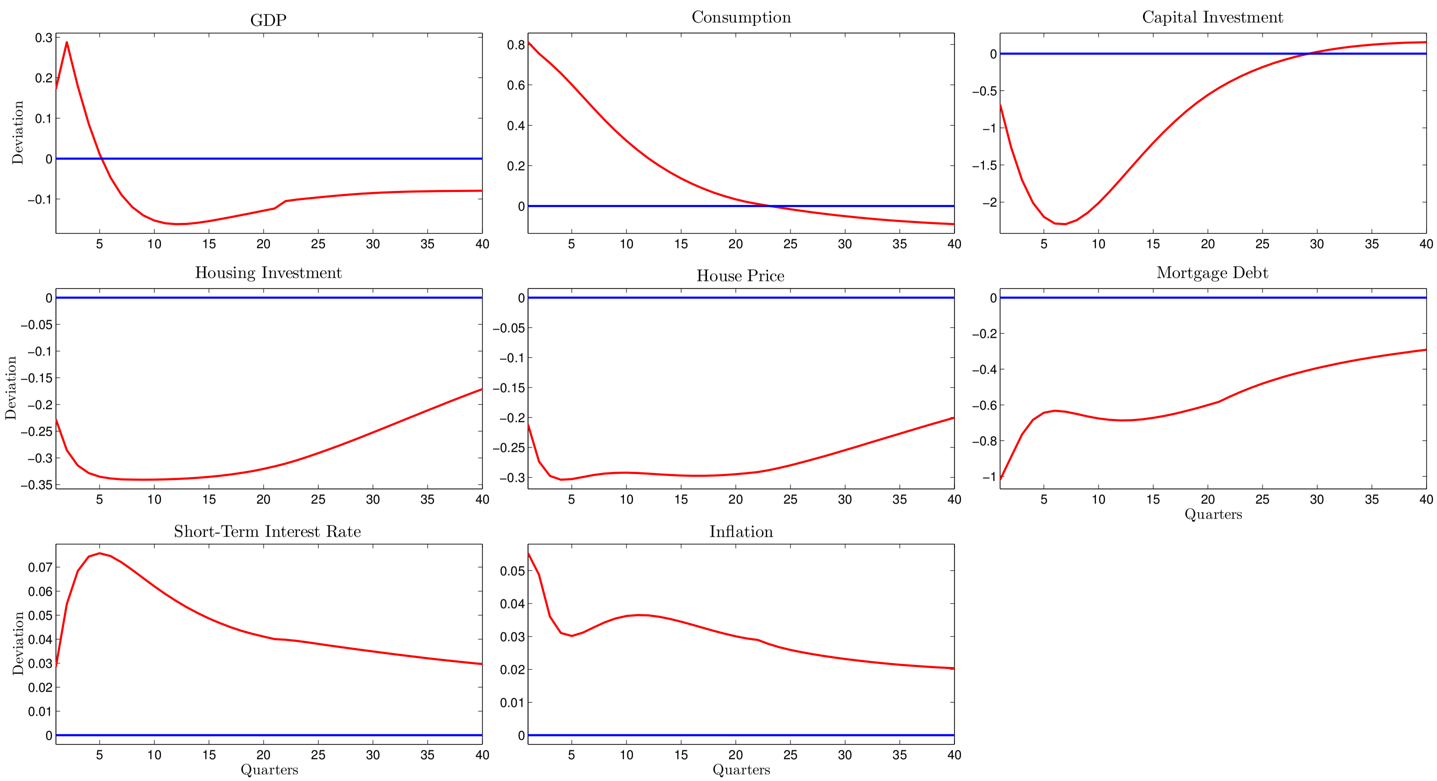


Figure 3.4: Shock Responses - Preference Shock

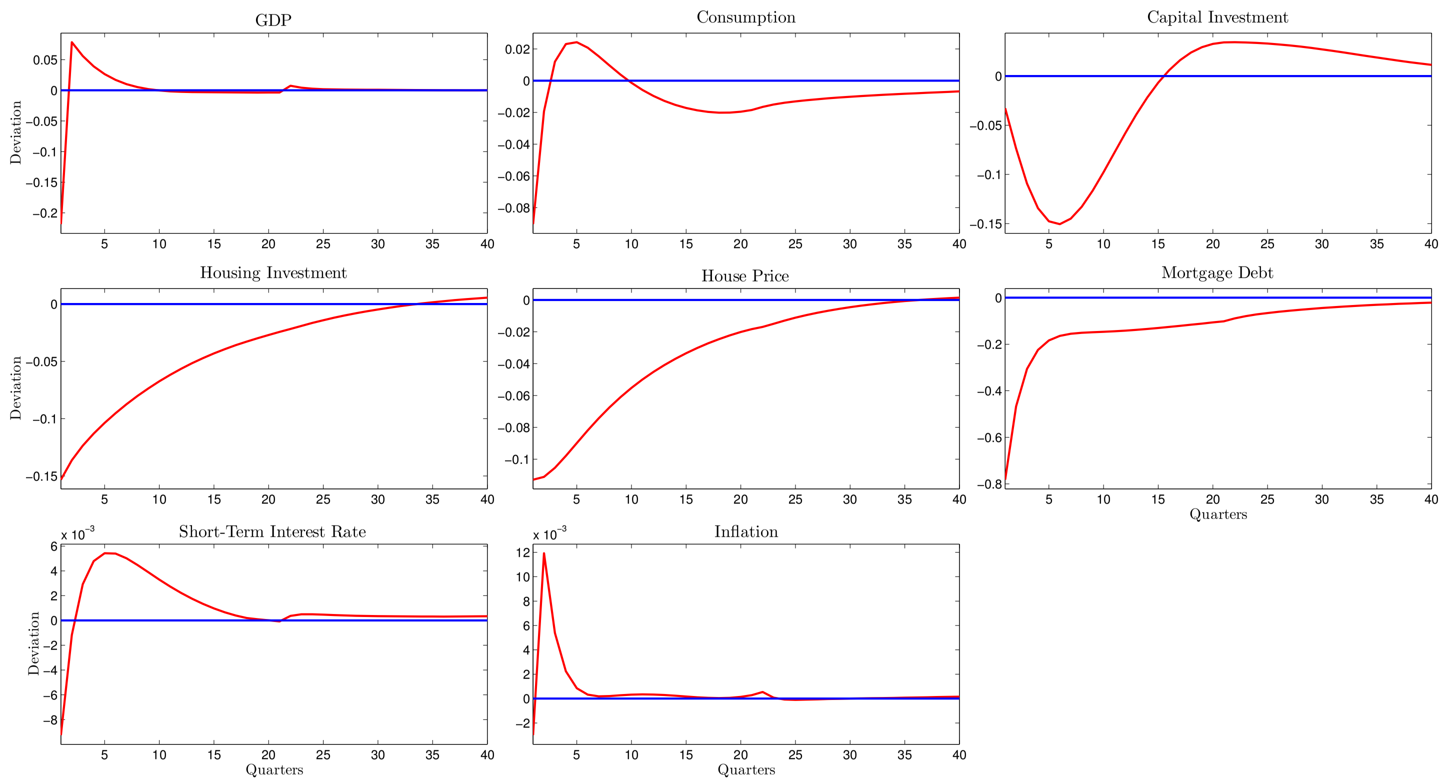


Figure 3.5: Shock Responses - Mortgage Premium Shock

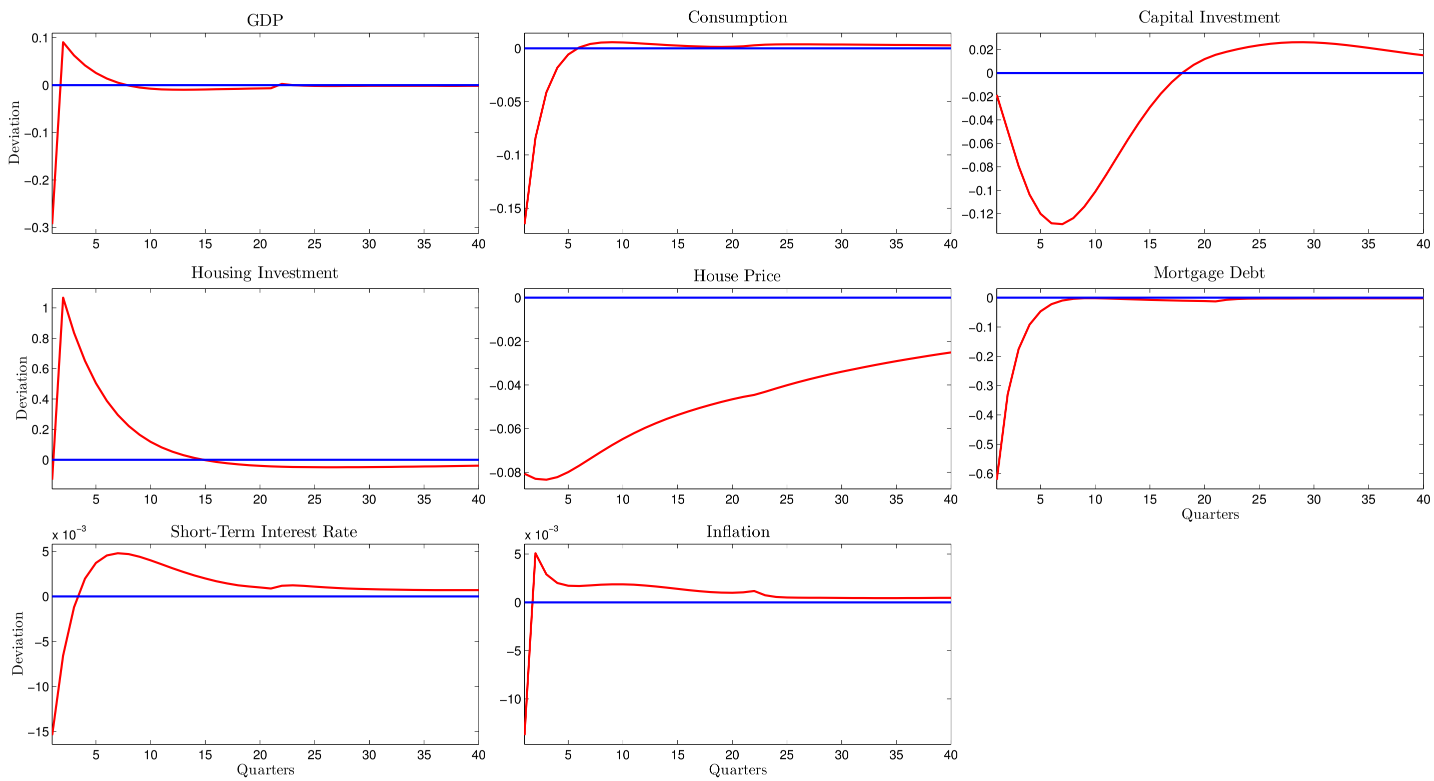


Figure 3.6: Shock Responses - Land Stock Shock

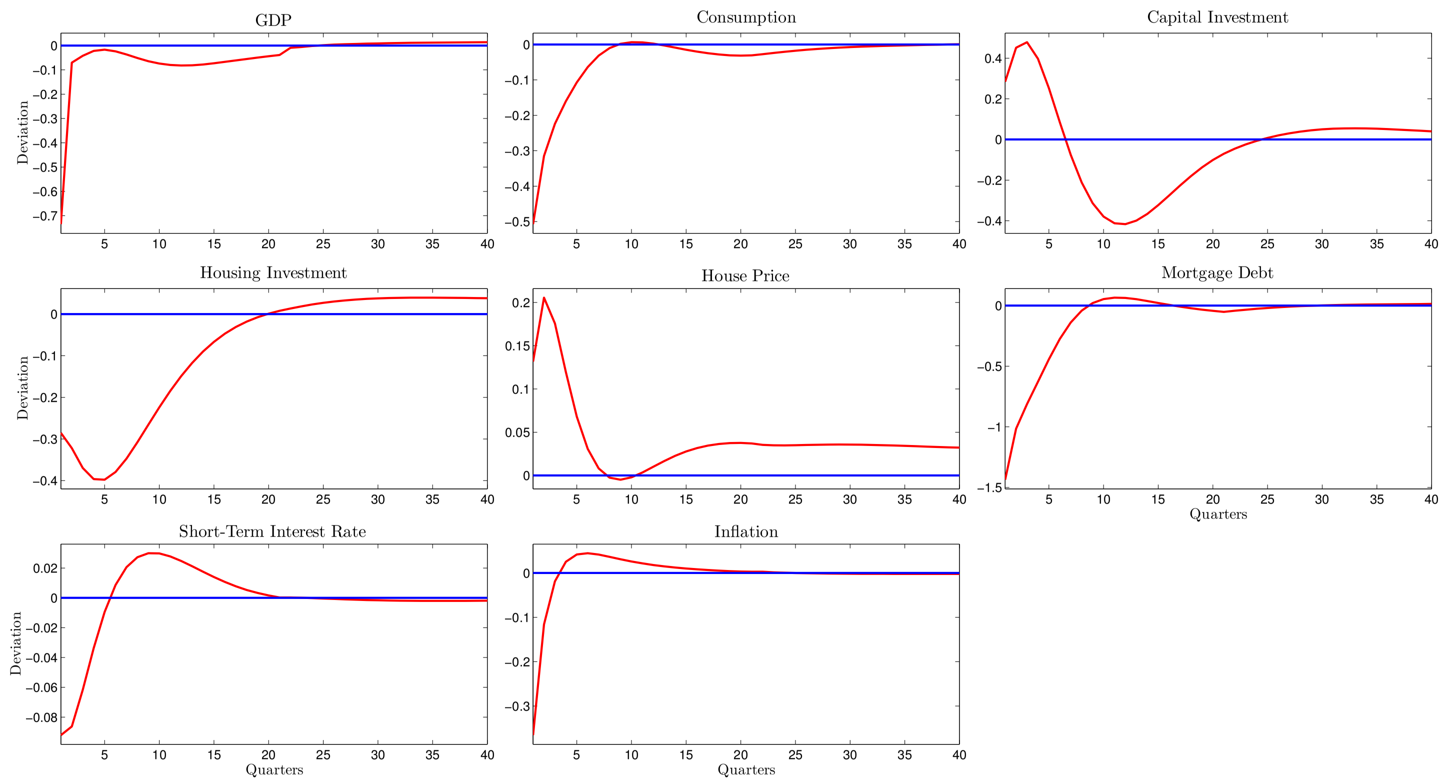


Figure 3.7: Shock Responses - TFP (Consumption Sector) Shock

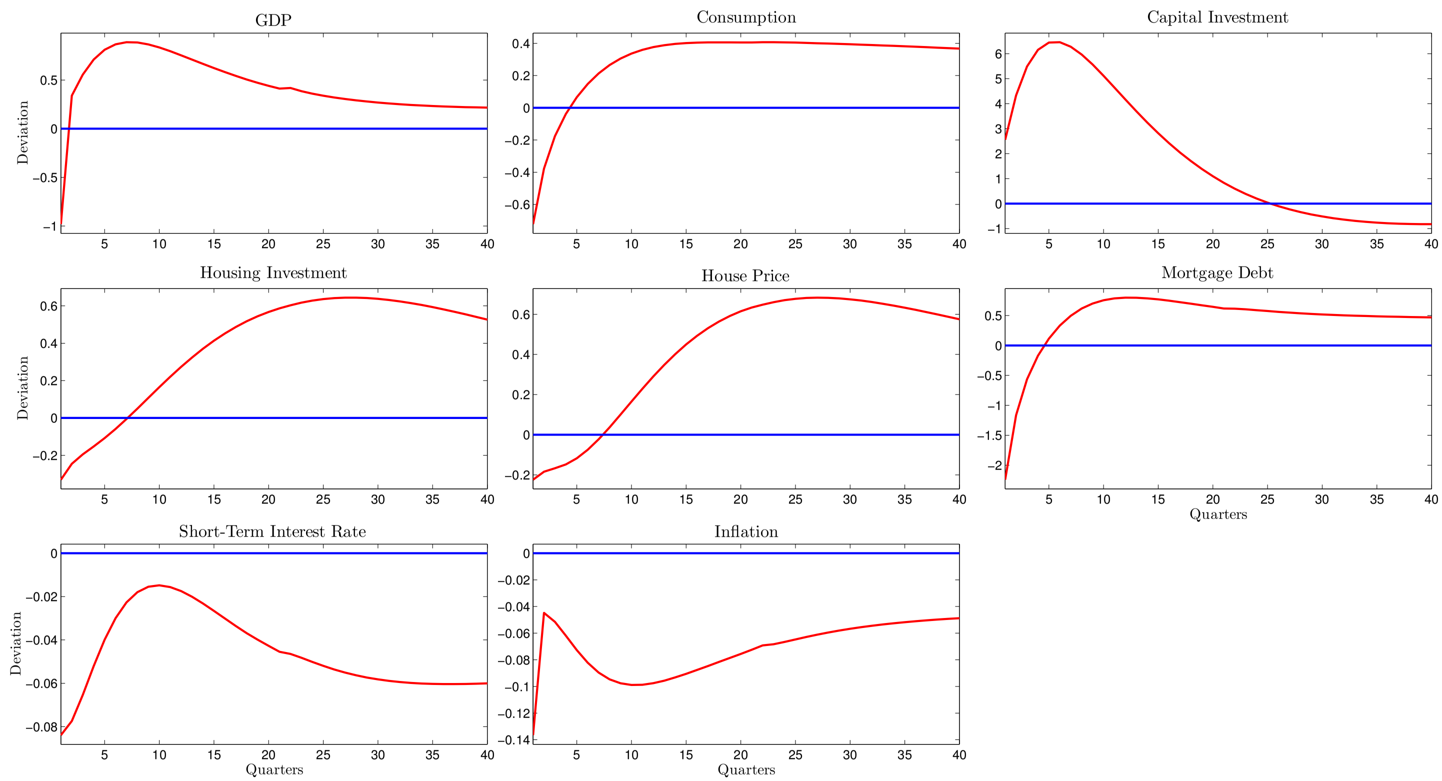


Figure 3.8: Shock Responses - Investment Shock

3.3 Optimization

Lagrangian for lenders optimization problem

$$
\begin{aligned}
L =& E_0 \sum_{t=0}^{\infty} \beta_P^t \epsilon_t^b U\left(c_{P,t}, h_{P,t}, n_{P,t}^c, n_{P,t}^h\right) + \lambda_{P,t}^c \times \\
&\left\{\begin{array}{l}
n_{P,t}^{c,d} \int\limits_0^1 w_{P,l,t}^c \left(\frac{w_{P,l,t}^c}{w_{P,t}^c}\right)^{-\theta^{n^c}} dl + n_{P,t}^{h,d} \int\limits_0^1 w_{P,l,t}^h \left(\frac{w_{P,l,t}^h}{w_{P,t}^h}\right)^{-\theta^{n^h}} dl \\
+ r_t^{k^c} u_t^{k^c} k_{t-1}^c + r_t^{k^h} u_t^{k^h} k_{t-1}^h + \left(q_t^l + r_t^l\right) l_{t-1} + \frac{R_{t-1} b_{P,t-1}}{\pi_t^c} + f_t^c + f_t^h + f_t^{fi} \\
+ \frac{1}{\phi^m} \sum_{s=1}^{\phi^m} \frac{d_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} + \sum_{s=1}^{\phi^m} \left(R_{t-s}^d - 1\right) \left(\frac{\phi^m - s + 1}{\phi^m}\right) \frac{d_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} \\
- c_{P,t} - q_t^{k^c} i_t^{k^c} - q_t^{k^h} i_t^{k^h} - q_t^l l_t - b_{P,t} - d_t \\
- q_t^h \left[h_{P,t} - \left(1 - \delta^h\right) h_{P,t-1}\right] \\
- q_t^{k^c} \left[k_t^c - \left(1 - \delta_t^{k^c}\right) k_{t-1}^c - z_t^{ik} i_t^{k^c} \left[1 - \frac{\phi^{k^c}}{2} \left(\frac{i_t^{k^c}}{i_{t-1}^{k^c}} - 1\right)^2 i_t^{k^c}\right]\right] \\
- q_t^{k^h} \left[k_t^h - \left(1 - \delta_t^{k^h}\right) k_{t-1}^h - z_t^{ik} i_t^{k^h} \left[1 - \frac{\phi^{k^h}}{2} \left(\frac{i_t^{k^h}}{i_{t-1}^{k^h}} - 1\right)^2 i_t^{k^h}\right]\right] \\
+ \frac{w_{P,t}^c}{\lambda_{P,t}^{n^c}} \left[n_{P,t}^c - n_{P,t}^{c,d} \int\limits_0^1 \left(\frac{w_{P,l,t}^c}{w_{P,t}^c}\right)^{-\theta^{n^c}} dl\right] + \frac{w_{P,t}^h}{\lambda_{P,t}^{n^h}} \left[n_{P,t}^h - n_{P,t}^{h,d} \int\limits_0^1 \left(\frac{w_{P,l,t}^h}{w_{P,t}^h}\right)^{-\theta^{n^h}} dl\right]
\end{array}\right\}
\end{aligned}
$$

Lagrangian for borrowers optimization problem

$$
\begin{aligned}
L =& E_0 \sum_{t=0}^{\infty} \beta_I^t \epsilon_t^b U\left(c_{I,t}, h_{I,t}, n_{I,t}^c, n_{I,t}^h\right) + \lambda_{I,t}^c \times \\
&\left\{\begin{array}{l}
n_{I,t}^{c,d} \int\limits_0^1 w_{I,l,t}^c \left(\frac{w_{I,l,t}^c}{w_{I,t}^c}\right)^{-\theta^{n^c}} dl + n_{I,t}^{h,d} \int\limits_0^1 w_{I,t}^h \left(\frac{w_{I,l,t}^h}{w_{I,t}^h}\right)^{-\theta^{n^h}} dl \\
+ \frac{R_{t-1}^m b_{I,t-1}}{\pi_t^c} + m_t - c_{I,t} - b_{I,t} - q_t^h \left[h_{I,t} - \left(1 - \delta^h\right) h_{I,t-1}\right] \\
- \frac{1}{\phi^m} \sum_{s=1}^{\phi^m} \frac{m_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} - \sum_{s=1}^{\phi^m} \left(R_{t-s}^m - 1\right) \left(\frac{\phi^m - s + 1}{\phi^m}\right) \frac{m_{t-s}}{\prod_{v=-s}^{0} \pi_{t+v}^c} \\
+ \frac{w_{I,t}^c}{\lambda_{I,t}^{n^c}} \left[n_{I,t}^c - n_{I,t}^{c,d} \int\limits_0^1 \left(\frac{w_{I,l,t}^c}{w_{I,t}^c}\right)^{-\theta^{n^c}} dl\right] + \frac{w_{I,t}^h}{\lambda_{I,t}^{n^h}} \left[n_{I,t}^h - n_{I,t}^{h,d} \int\limits_0^1 \left(\frac{w_{I,l,t}^h}{w_{I,t}^h}\right)^{-\theta^{n^h}} dl\right] \\
+ \lambda_{I,t}^b \left[M_t + \omega h_{I,t} q_t^h\right]
\end{array}\right\}
\end{aligned}
$$

Lagrangian for wages optimization problem (for $i \in \{P, I\}$ and $j \in \{c, h\}$)

$$L = E_t \sum_{s=0}^{\infty} \left(\beta_i \xi^{w^j}\right)^s \lambda^c_{i,t+s} n^{j,d}_{i,t+s} \left(\frac{\tilde{w}^j_{i,t}}{w^j_{i,t+s}}\right)^{-\theta^{n^j}} \prod_{k=1}^{s} \left(\frac{1}{\pi^c_{t+k}}\right)^{-\theta^{n^j}} \left[\tilde{w}^j_{i,t} \prod_{k=1}^{s} \left(\frac{1}{\pi^c_{t+k}}\right) - \frac{w^j_{i,t+s}}{\lambda^{n^j}_{i,t+s}}\right]$$

Lagrangian for prices optimization problem

$$L = E_t \sum_{s=0}^{\infty} \left(\beta_P \xi^{p^c}\right)^s \frac{\lambda^c_{P,t+s}}{\lambda^c_{P,t}} \frac{P^c_t}{P^c_{t+s}} \left\{ \begin{array}{c} \left[\begin{array}{c} \tilde{P}^c_t \left(\frac{\tilde{P}^c_t}{P^c_{t+s}}\right)^{-\theta^c} y^c_{t+s} - r^{k^c}_{t+s} k^c_{m,t+s} \\ -w^c_{P,t+s} n^{c,d}_{P,m,t+s} - w^c_{i,t+s} n^{c,d}_{i,m,t+s} \end{array} \right] \\ +MC_{m,t+s} \times \\ \left[\begin{array}{c} z^c_{t+s} \left(k^c_{m,t+s}\right)^{\gamma^c} \left(\left(n^{c,d}_{P,m,t+s}\right)^{\alpha} \left(n^{c,d}_{i,m,t+s}\right)^{1-\alpha}\right)^{1-\gamma^c} \\ - \left(\frac{\tilde{P}^c_t}{P^c_{t+s}}\right)^{-\theta^c} y^c_{t+s} \end{array} \right] \end{array} \right\}$$

3.4 Loan-to-Value Ratio Policy in Canada

- In March 2004, the CMHC *Flex Down* program broadened the eligible sources of funds for the minimum down payment (set at 5 percent).
- In March 2006, the CMHC allowed 0 percent down payment and extend the maximum amortization period to 30 years.
- In April 2007, the LTV limit for insured loans increased to 80 percent from 75 percent and the maximum amortization period is extended to 40 years.
- In October 2008, the maximum LTV for insured loans was reduced from 100 percent to 95 percent and the maximum amortization period for new government backed insured mortgages was lowered from 40 to 35 years.
- In April 2010, the maximum LTV for refinanced mortgages was lowered from 95 percent to 90 percent and the minimum down payment on properties not occupied by owner was raised from 5 percent to 20 percent.
- In March 2011, the maximum LTV for refinanced mortgages was lowered from 90 percent to 85 percent and the maximum amortization for new government backed insured mortgages was lowered from 35 to 30 years.
- In June and July 2012, the maximum LTV on HELOCs was lowered from 80 percent to 65 percent, the maximum LTV for refinanced mortgages was lowered from 85 percent to 80 percent and the maximum amortization for new government backed insured mortgages was lowered from 30 to 25 years.